3

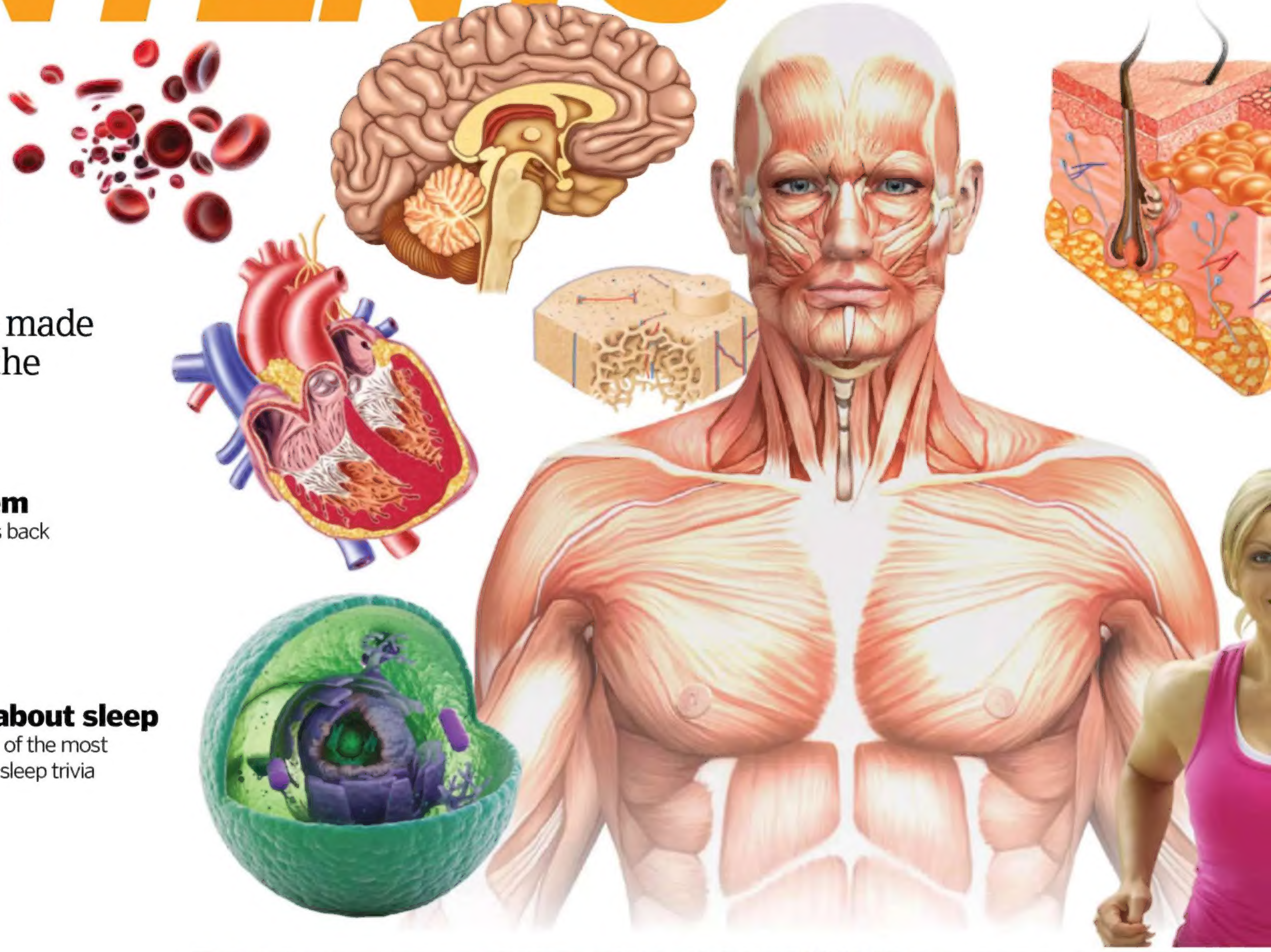
HOW IT WORKS

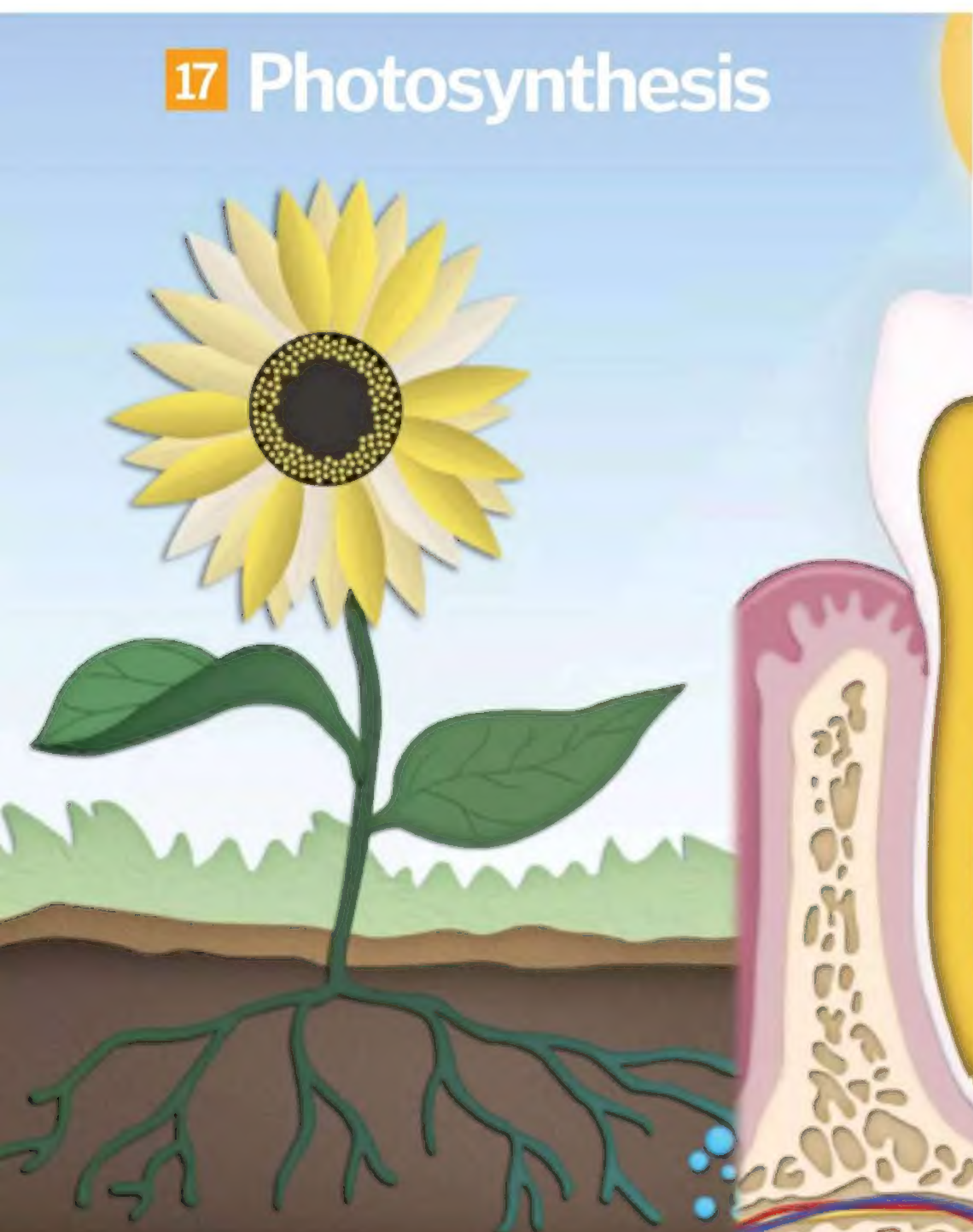
AMAZING BIOLOGY

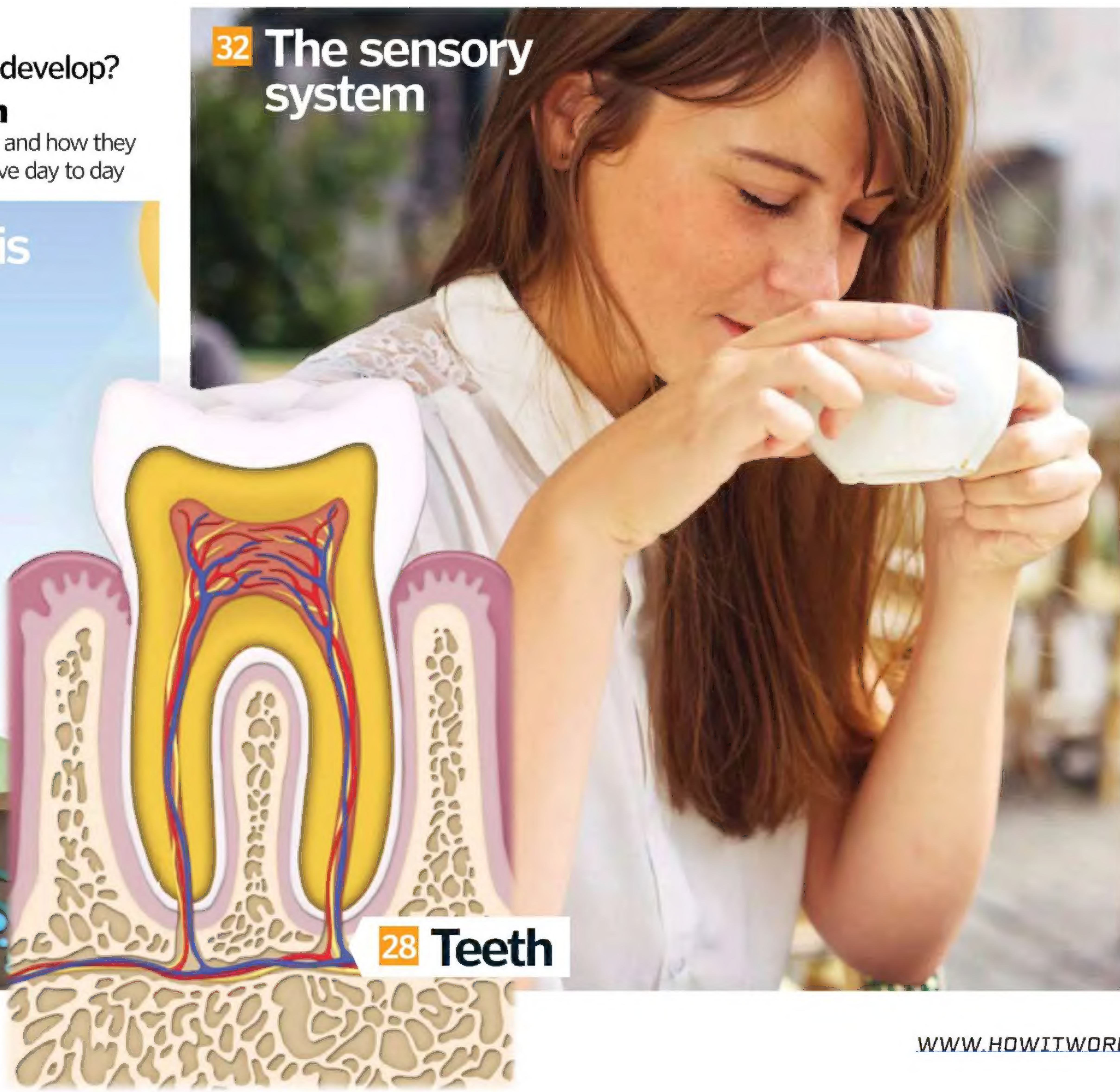
CONTENTS

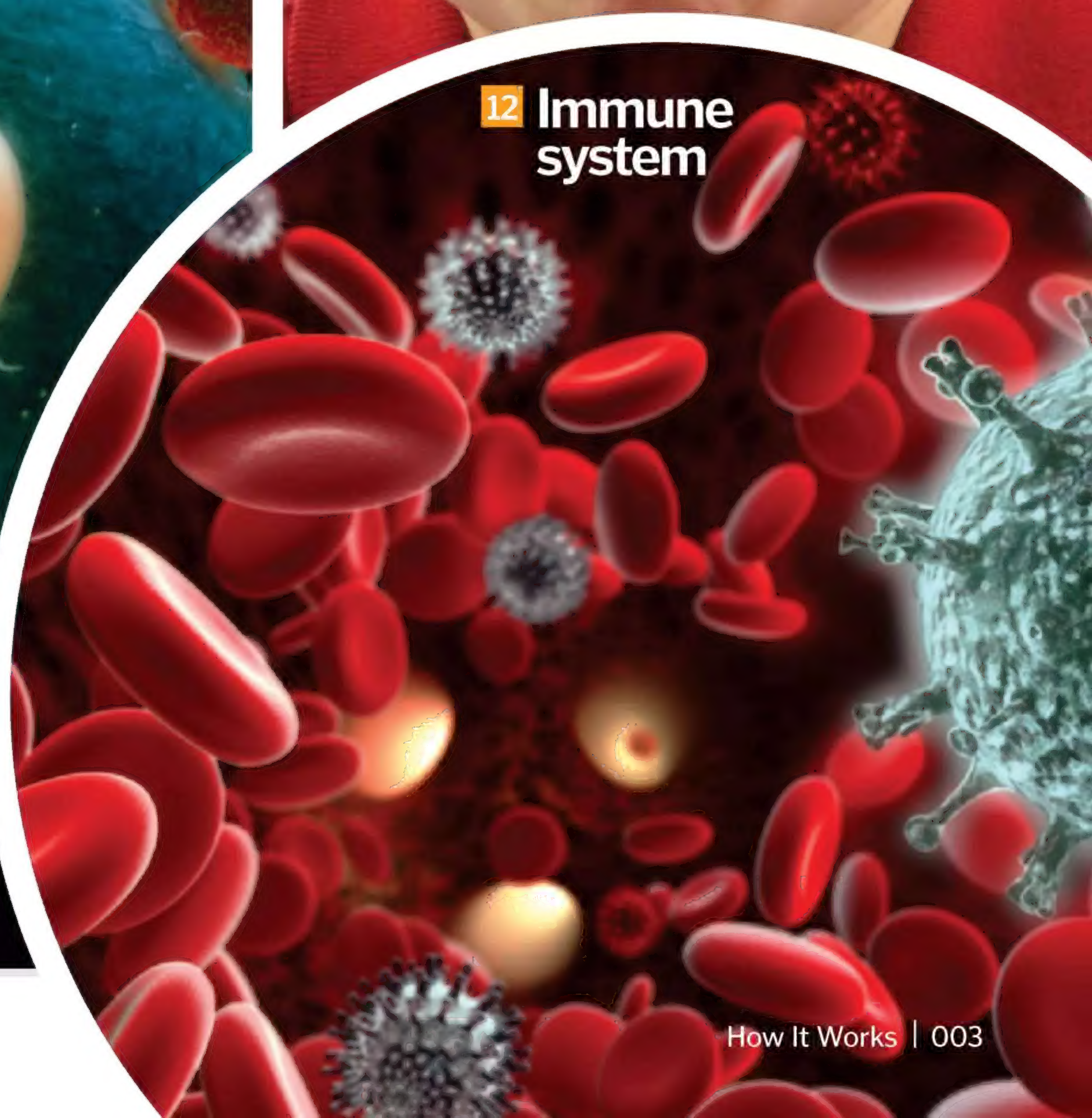
4 THE HUMAN BODY

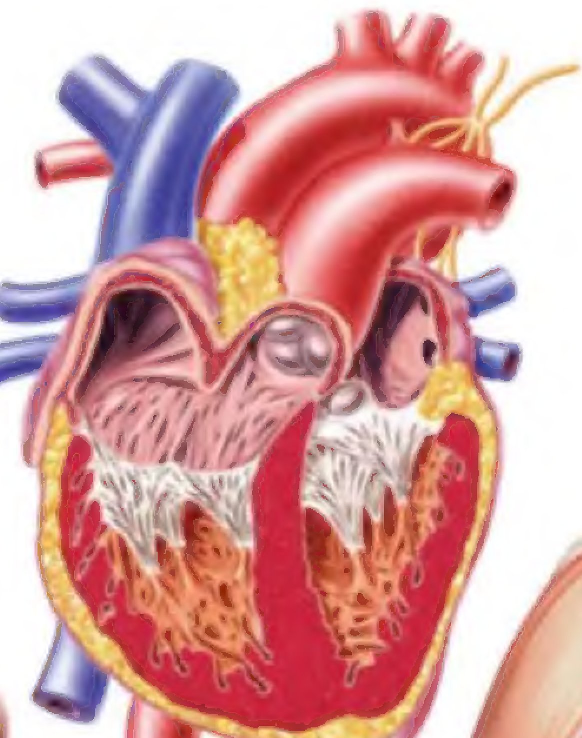
Find out what you're made of with our guide to the human body



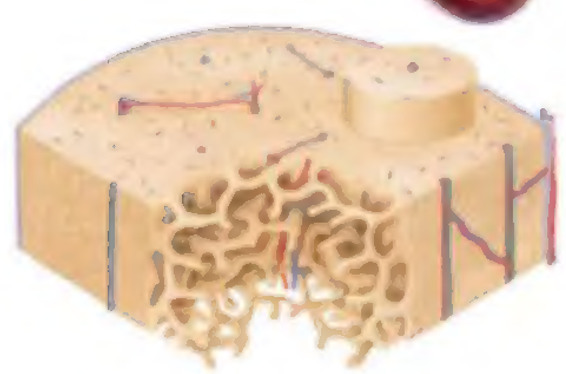


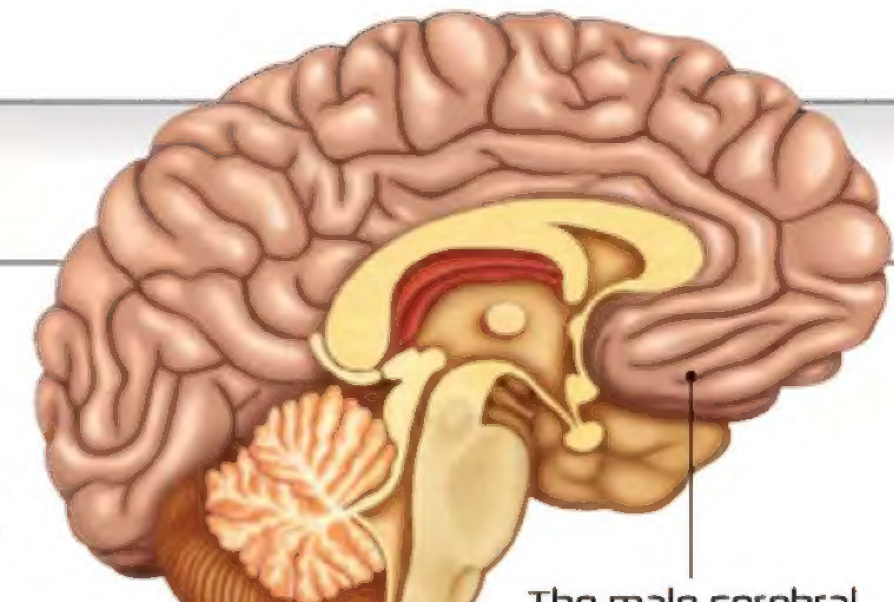


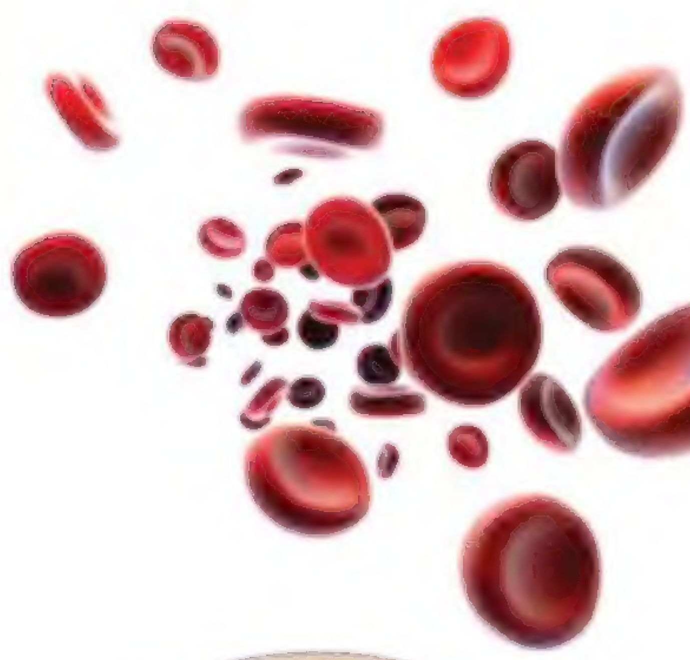


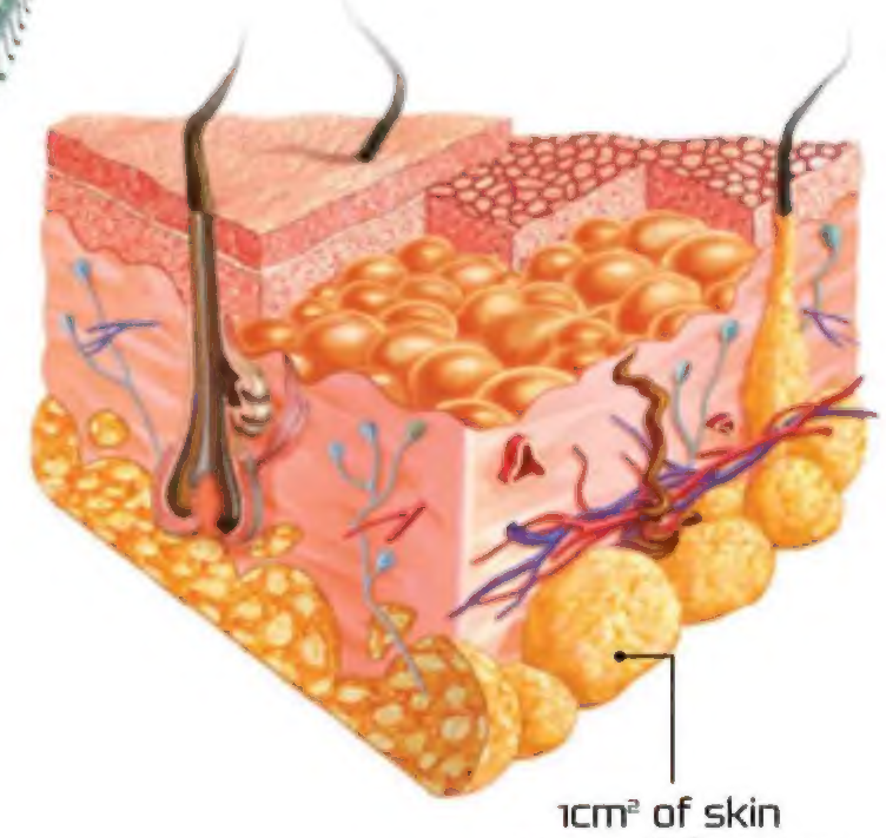


Making connections
The hyoid in the neck is the only bone that isn't connected to another bone









THE HUMAN BODY

Journey inside the body to discover just what we are made of…

The human body is composed of an estimated 7 octillion (which written out is 7,000,000,000,000,000,000,000,000,000) atoms, making up over 75 trillion cells.

At the atomic level, the human body comprises about 60 elements, but the function of many of them is unknown. In fact, 99 per cent of the human body is made from just six elements (see chart for specific percentages).

Like all other life discovered to date, we are carbon-based; the biomolecules that make up our bodies are constructed using frameworks of carbon atoms. Carbon is almost unique among the elements; it is small in size and can make four covalent bonds to other atoms, allowing it to form the backbone of key molecules that form the human body, including proteins, fats, sugars and DNA. The bonds are strong enough to hold the molecules in a stable structure, but not so strong that they cannot be taken apart again, allowing the body to break and reform molecules over and over as required.

Calcium is the most abundant mineral in the human body, important for the regulation of protein production and activity.

Complex cascades of chemical reactions occur within the gel-like cytoplasm and organelles of cells – tiny structures that perform specific functions within a cell. Phosphorus is used to make adenosine triphosphate (ATP), which has high-energy phosphate bonds that can be broken in order to power cellular processes; ATP is essentially our cells' fuel.

Cells are coated in receptors and respond rapidly to environmental changes, communicating via chemical signals and electrical impulses. During embryonic development, chemical gradients tell developing cells where to go, and what cell type to become, resulting in a new person.

Interestingly, the majority of the cells in the human body are not human. Microbes make up between one and three per cent of our body mass and are hugely important for our proper functioning. They have 8 million different coding genes for making proteins, compared to less than 30,000 in the human genome.

The bacteria that live in our digestive system provide essential support too; they ferment undigested carbohydrates, allowing us to access energy we couldn't otherwise digest, and they have a role in the production of vitamins like biotin and vitamin K. Their presence in the gut also prevents 'bad' bacteria from taking hold and making us unwell. Even more unusually, at least eight per cent of the human genome is viral in origin. Retroviruses are able to insert their DNA into our chromosomes, and at several points in human evolution genes that started out in viruses have become permanently entwined with our own genetic information.

How many hairs?
A human head has an average of 100,000 to 150,000 hairs

5 TOP FACTS
BODY MAKEUP

Empty space
1 Interestingly, atoms mostly consist of space. If all of our bodily atoms were compressed like a neutron star, the human body would fit into a one-500th-centimetre cube.

Mostly water
2 Over half of the body is water. It acts as a solvent for the chemical reactions that drive cells, carries nutrients around the body and also helps to regulate temperature.

Pigmented bodies
3 Body pigments don't just determine skin, eye and hair colour. Red haemoglobin in the blood transports oxygen, while purple rhodopsin allows us to see in dim light.

Hairy ape
4 Humans have the same number of hair follicles as a chimpanzee does. However, during evolution we lost the function of a gene that helps to produce keratin.

Vestigial organs
5 The body has characteristics left over by evolution no longer in use. Wisdom teeth used to be handy for grinding down plant tissue and the coccyx represents a tail.

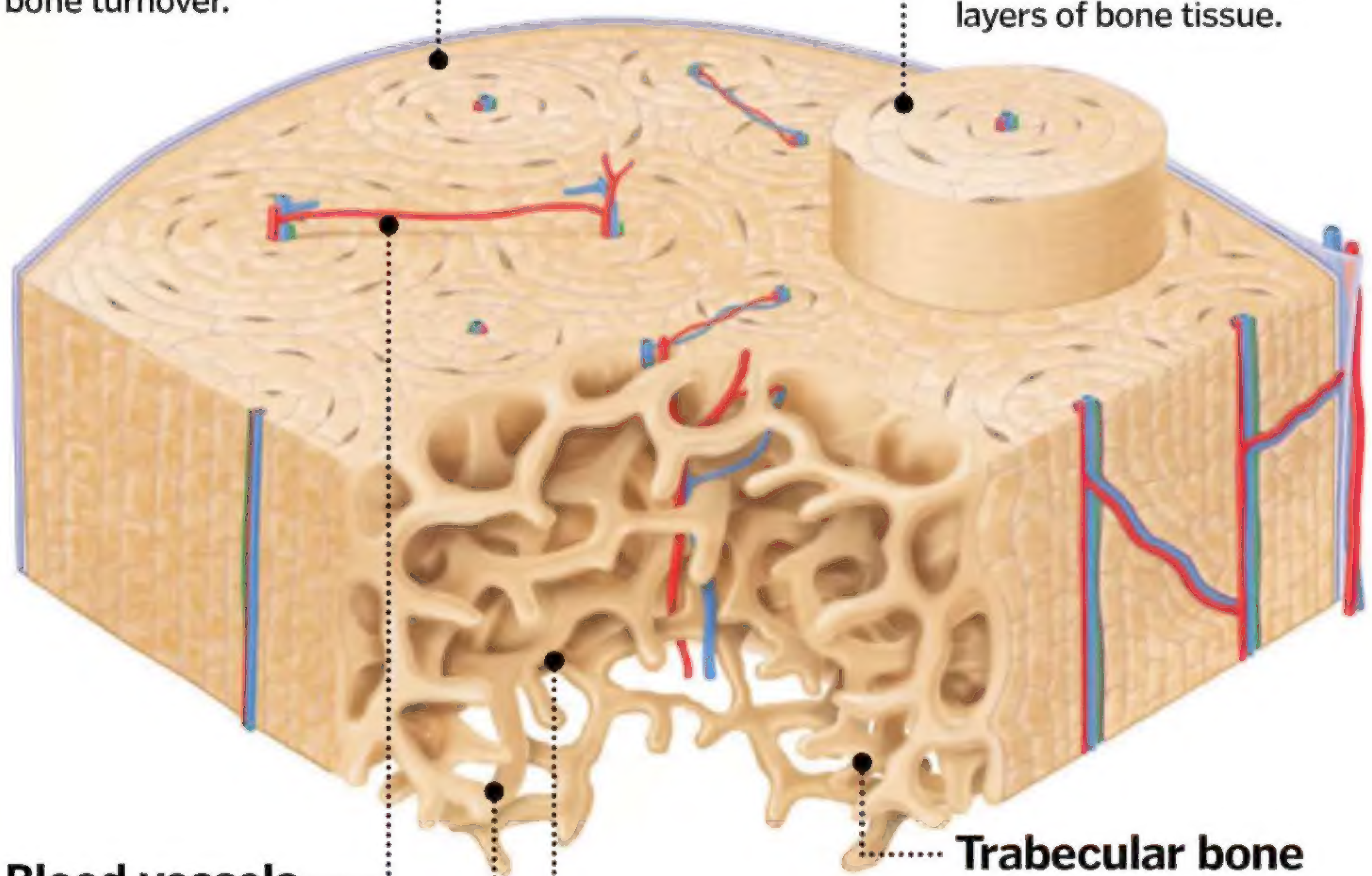
DID YOU KNOW? *Bone works like reinforced concrete with its collagen fibres the steel supports and the minerals cement*

The structure of bones

The long bones of the body, such as the femur (thighbone), contain two distinct types of bone

Osteocyte
The cells that form the bone matrix eventually become trapped in it. They help to regulate bone turnover.

Cortical bone
The tough outer layer of bones contains densely packed cylindrical structures – osteons – formed from concentric layers of bone tissue.



Blood vessels
Bone is a metabolically active tissue and a good blood supply allows for mineral exchange.

Trabecular bone
Within the ends of long bones is a looser, honeycomb structure, where calcium is released from storage as required.

Osteoblast
Osteoblasts make new bone, producing the collagen scaffold and laying down minerals.

Osteoclast
Osteoclasts are related to cells of the immune system and digest old bone to release minerals and allow for remodelling.

Beneath the skin

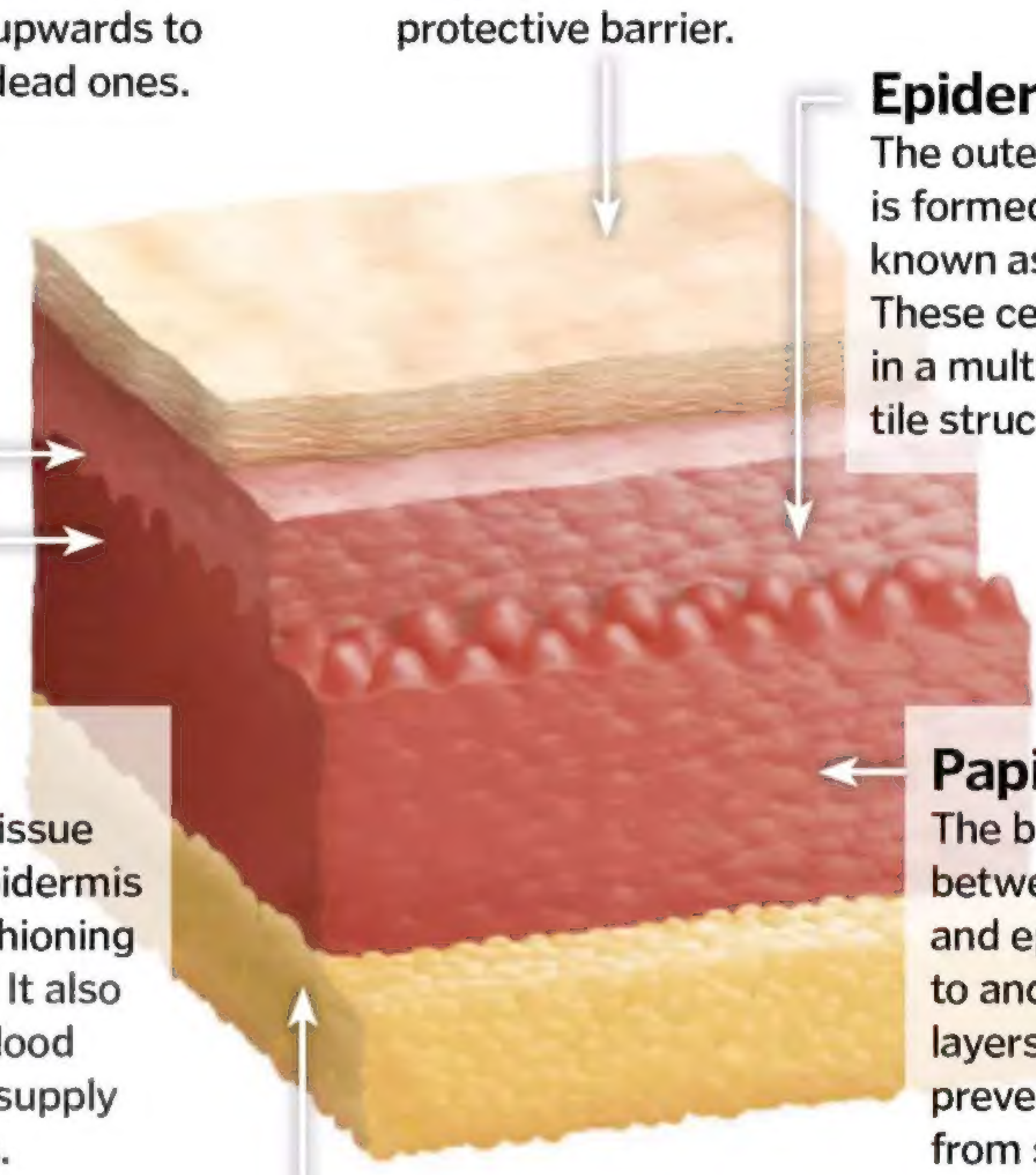
Skin has several layers with a unique function.

Largest organ of the body
The skin of a human adult measures two square metres (22 square feet)

Stem cells
A layer of stem cells at the base of the epidermis divides to form new skin cells, which push upwards to replace the dead ones.

Cornified layer
The very outer layer of the skin consists entirely of flattened, dead cells. These provide a protective barrier.

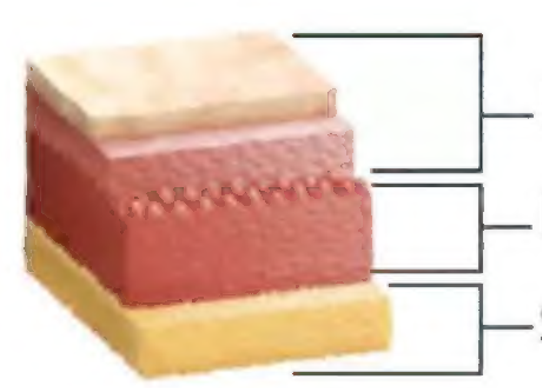
Epidermis
The outer layer of skin is formed of cells known as keratinocytes. These cells arrange in a multilayered tile structure.



Dermis
Connective tissue below the epidermis provides cushioning and support. It also carries the blood vessels that supply the skin cells.

Papillae
The bumpy structure between the dermis and epidermis helps to anchor the two layers together, preventing them from slipping.

Fat
A layer of subcutaneous adipose tissue provides cushioning and insulation, as well as energy storage.



Hair under the microscope

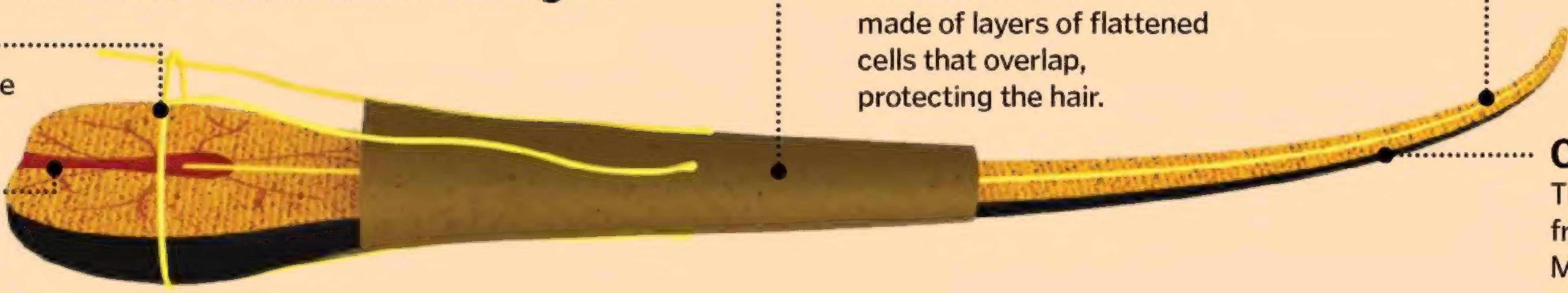
A strand of hair can be divided into three distinct regions

Matrix
Cells of the matrix divide to produce new hair.

Papillae
Blood vessels supply nutrients to the cells of the matrix and root.

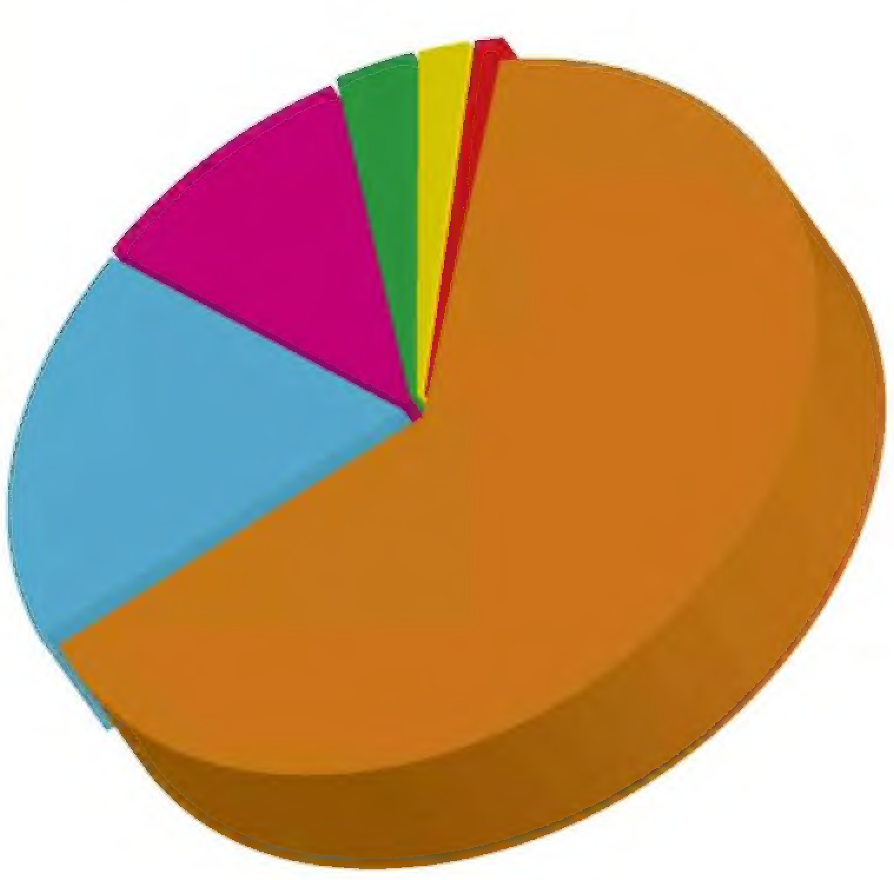
Cuticle
The outside of the hair is made of layers of flattened cells that overlap, protecting the hair.

Medulla
An open, unstructured core runs up the centre of the hair.



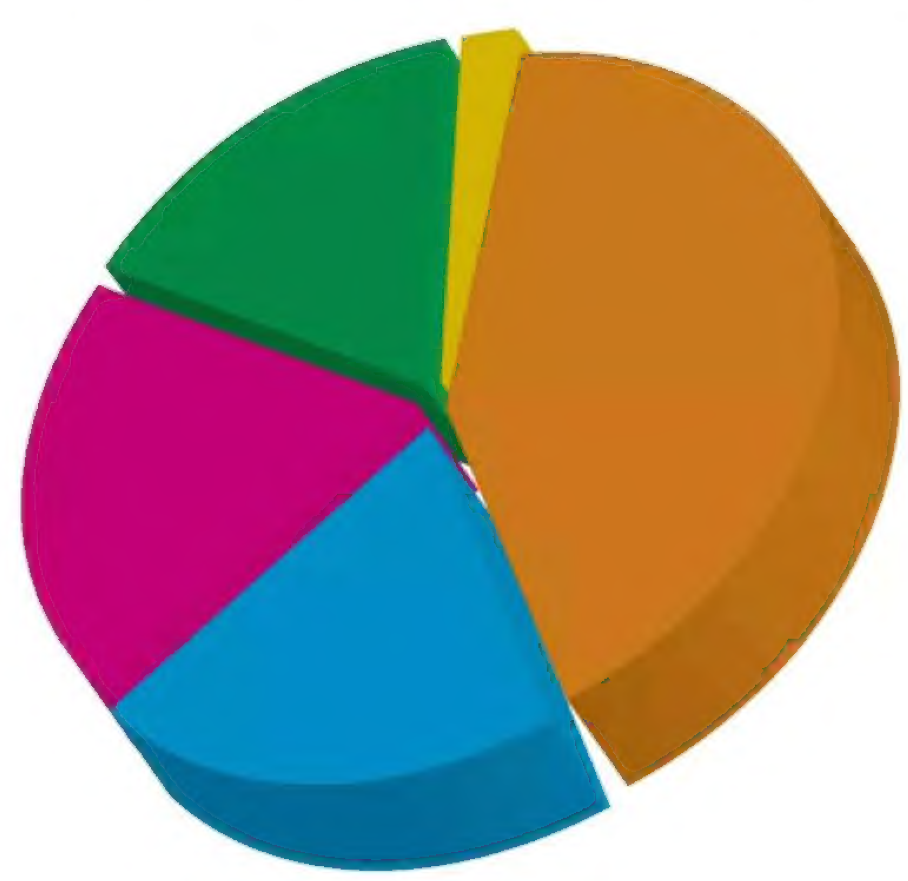
Cortex
The body of the hair is made from coiled strands of keratin. Melanin granules within the cortex lend it its colour.

Six main elements of the body (99%)



- **Oxygen:** 65%
- **Carbon:** 18%
- **Hydrogen:** 10%
- **Nitrogen:** 3%
- **Calcium:** 2%
- **Phosphorus:** 1%

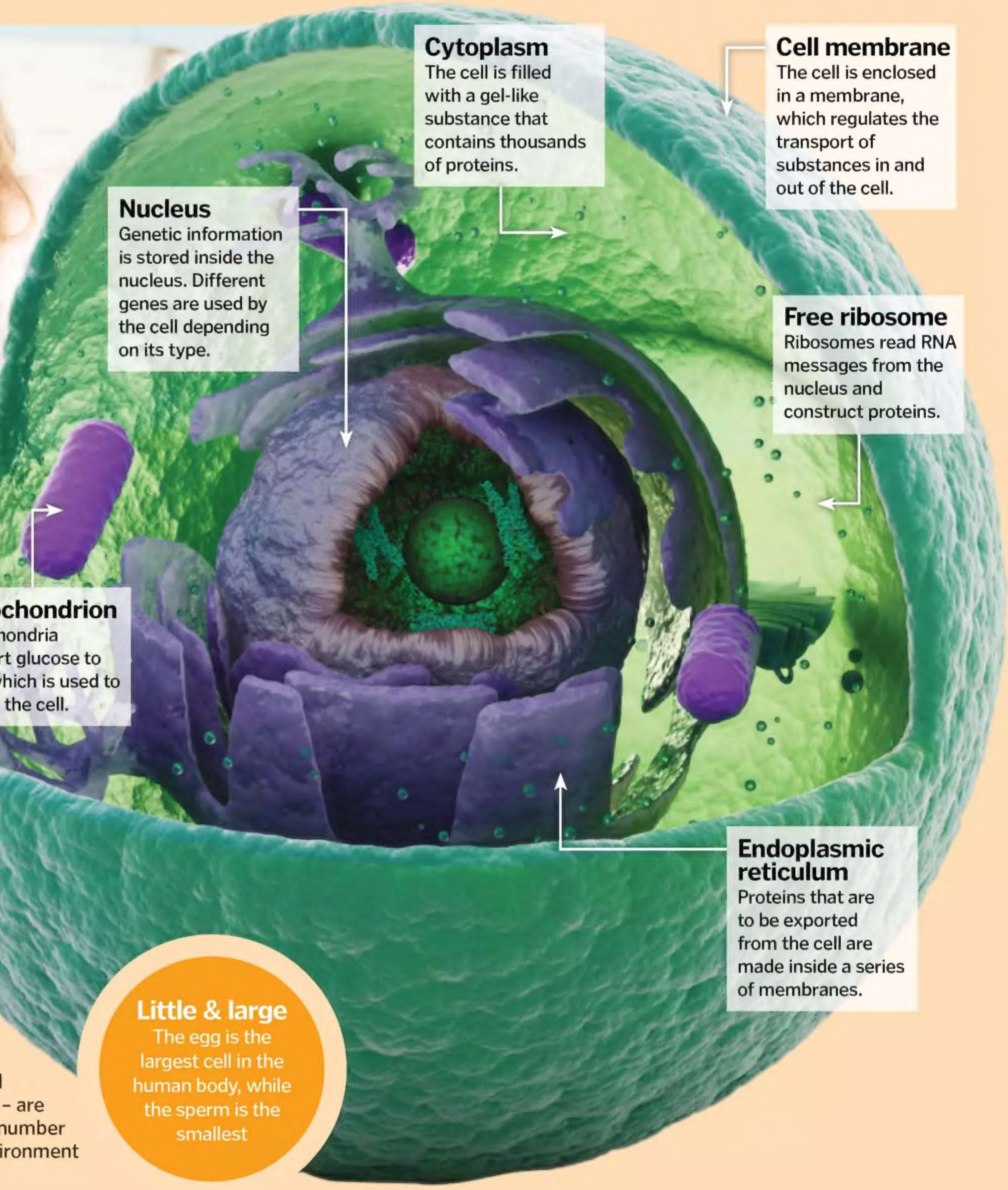
Body composition by tissue type



- **Skeletal muscle:** 36-42%
- **Fat:** 13-20%
- **Bone:** 12-20%
- **Skin:** 16%
- **Brain:** 2%

> “Red blood cells lack a nucleus, enabling them to pack in more of the oxygen-carrying haemoglobin”

The nucleus stores all sorts of genetic information



Close up with cells

There are thought to be over 200 different types of cell in the human body, each specialised to perform a particular function. Despite these specialisms, their basic underlying biology is the same.

Cells contain a nucleus, which houses the 46 chromosomes, containing the complete set of instructions to synthesise all of the proteins found in the human body. Depending on the type of cell, different genes are switched on and off, determining which proteins the cell will produce.

Proteins for use inside the cell are created on ribosomes in the cytoplasm. The ribosomes read the genetic message and assemble the corresponding protein using amino acids as building blocks. Proteins to be exported from the cell – for example, antibodies or digestive enzymes – are constructed within a series of membranes. Here they gain a number of modifications which enable them to survive the harsh environment when they leave the cell to travel around the body.

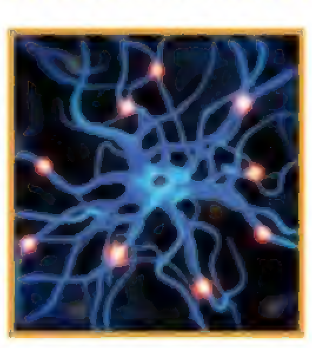
Little & large
The egg is the largest cell in the human body, while the sperm is the smallest

Key cells of the body

Blood and immune cells
Type: Blood
The cells of the blood, including red blood cells and the white blood cells of the immune system are all produced in the bone marrow. Red blood cells lack a nucleus, enabling them to pack more of the oxygen-carrying protein, haemoglobin, into their cytoplasm.

Epithelial cells
Type: Skin and membranes
The cells that cover our bodies and line our body cavities form junctions with one another. Using proteins anchored between their membranes, the cells join forces to create strong barriers to protect the body.

Contractile cells
Type: Muscle
These cells contain a protein ratchet system, which enables them to contract. Actin and myosin form long strands, which slide past one another, pulling the edges of the cell together.



Nerve cells
Type: Brain and nerves
Nerve cells have specialised membranes, which use molecular pumps to maintain an electrochemical gradient; this allows them to transmit electrical signals. Nerves function more efficiently if they are insulated and many nerve cells are covered by a fatty sheath of myelin.

Stem cells
Type: Undifferentiated
Stem cells are ones that have not yet committed to a particular specialism. They are found in many locations and provide a replicating reservoir of cells that can be used to maintain and repair the body.

Extracellular matrix cells
Type: Connective tissue
The cells of the body are supported by networks of fibres including collagen and elastin. These are generated by extracellular matrix cells like fibroblasts, which produce and secrete precursor components that then assemble into the fibres that make up the matrix.

Endocrine cells
Type: Hormones
These cells generate hormones and release them locally or into the bloodstream. Their hormone-releasing activity is controlled by neurotransmitters sent from local nerves, or by other chemical messengers, which bind to receptors that are on the cell surface.

Germ cell
Type: Reproductive
Sperm and egg cells have just one copy of each chromosome and are formed by a special type of cell division called meiosis. When sperm and egg combine, the resulting cell has a full set of 46 chromosomes.

THE STATS IN A LIFETIME...

BLINK 415mn times | DEAD SKIN 50kg | HAIR 1,500km | URINE 50,000 litres | FINGERNAILS 30m | HEARTBEATS 2.5bn

DID YOU KNOW? *The biggest molecule in the body is chromosome 1, a continuous strand of DNA containing 10 billion atoms*

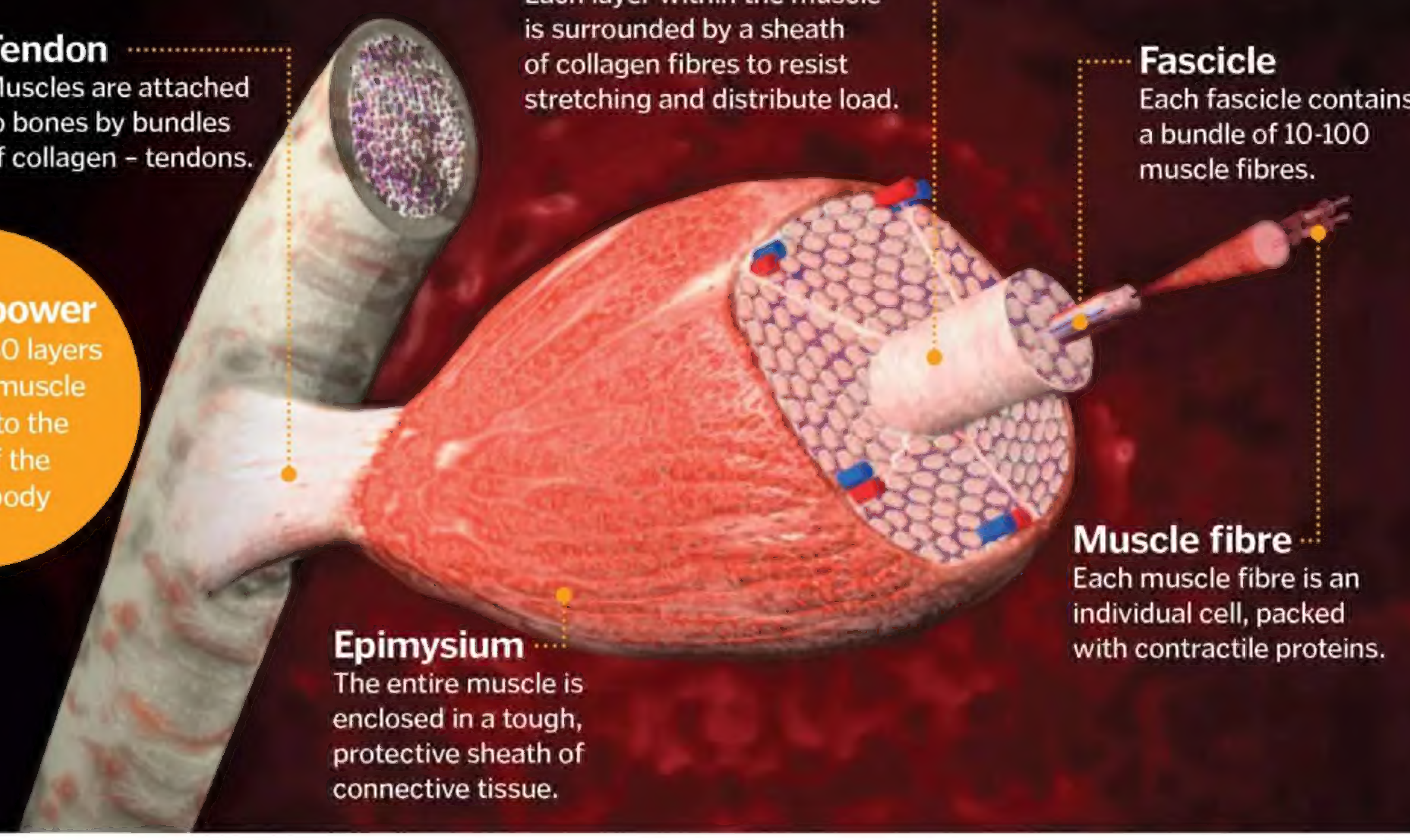
Muscle and movement

Skeletal muscle is responsible for moving the skeleton. It is composed of bundles of muscle fibres, sheathed in a strong collagen matrix, which extends into tendons that attach to the bone.

Within each muscle fibre is a molecular ratchet system made from the proteins actin and myosin. As the protein filaments slide past one another, the muscle fibre contracts lengthways and the fibre shortens.

Muscle fibres can be broadly categorised as being either 'fast twitch' or 'slow twitch'. Fast-twitch fibres use high-speed anaerobic respiration to produce rapid movements, but fatigue quickly. In contrast, slow-twitch fibres use sustainable aerobic respiration and produce slower movement for longer periods of time.

The proportion of slow and fast-twitch fibres affects athletic performance, eg long-distance runners have a higher proportion of slow-twitch fibres than sprinters. Whether muscle fibres can change from one to another is under investigation.



Tendon
Muscles are attached to bones by bundles of collagen – tendons.

Muscle power
There are 650 layers of striated muscle attached to the bones of the human body

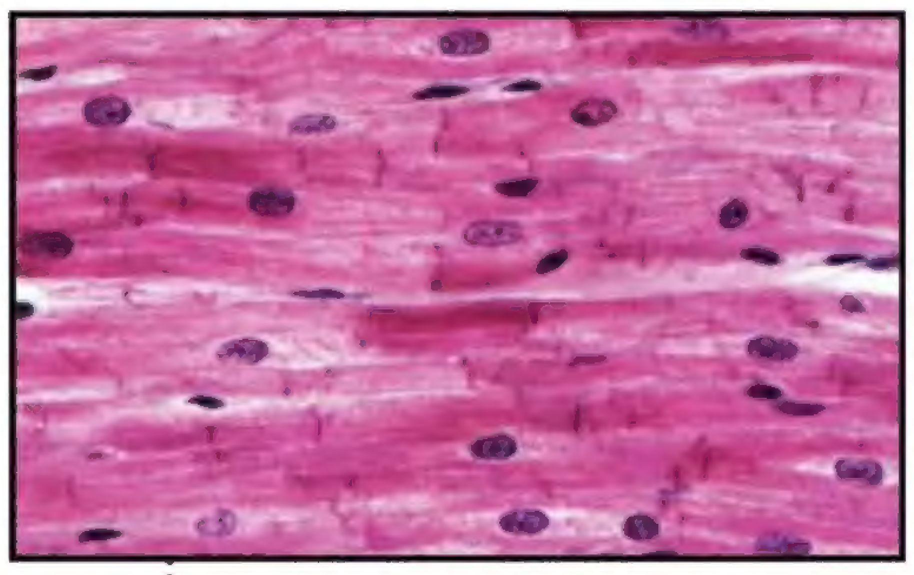
Connective tissue
Each layer within the muscle is surrounded by a sheath of collagen fibres to resist stretching and distribute load.

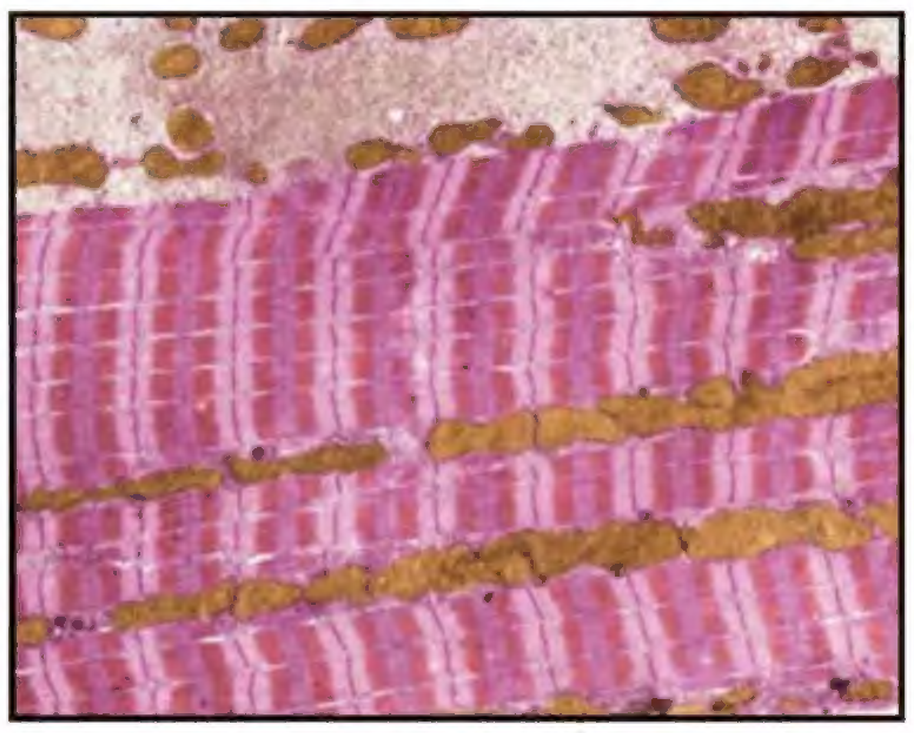
Fascicle
Each fascicle contains a bundle of 10-100 muscle fibres.

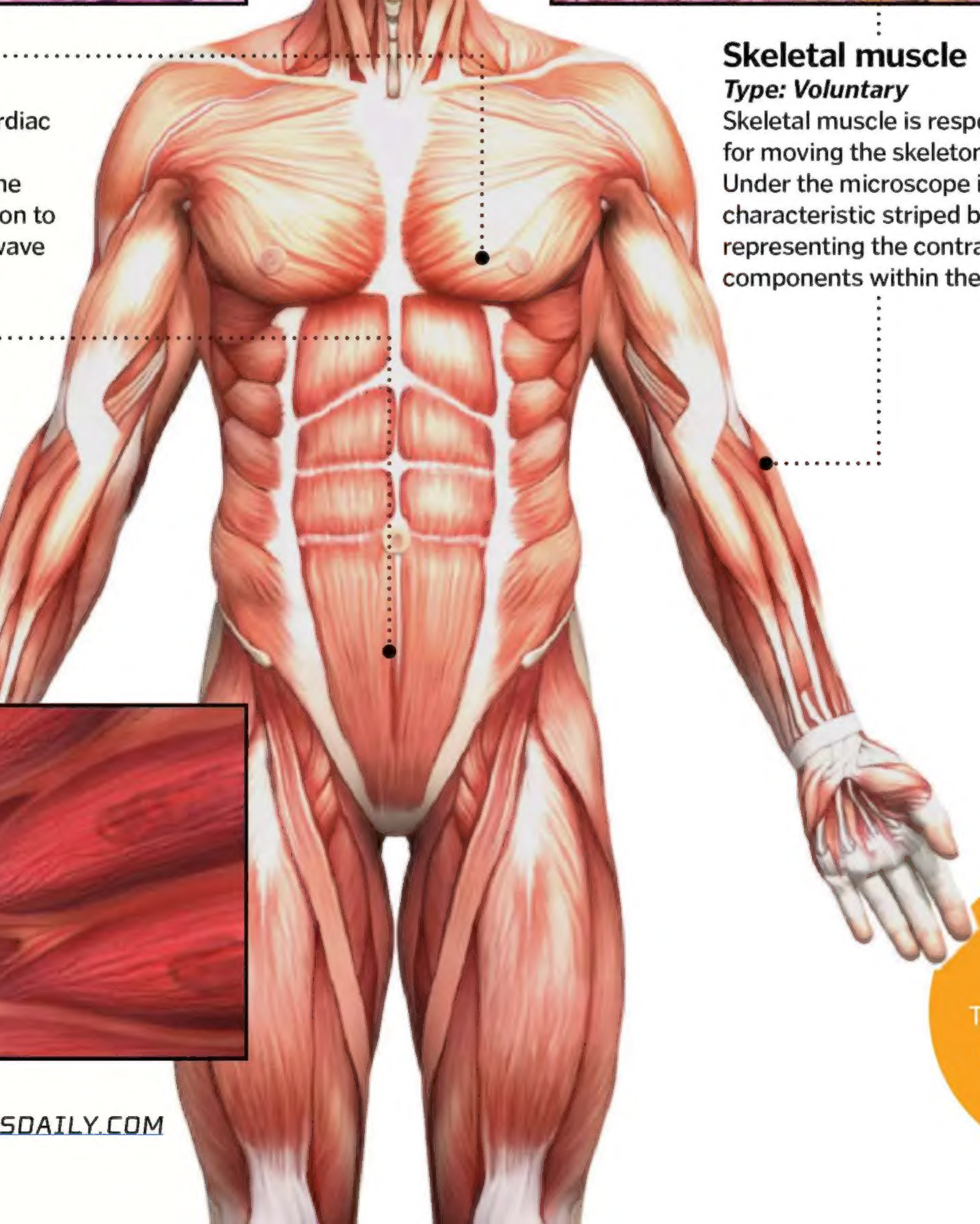
Muscle fibre
Each muscle fibre is an individual cell, packed with contractile proteins.

Epimysium
The entire muscle is enclosed in a tough, protective sheath of connective tissue.

Types of muscle



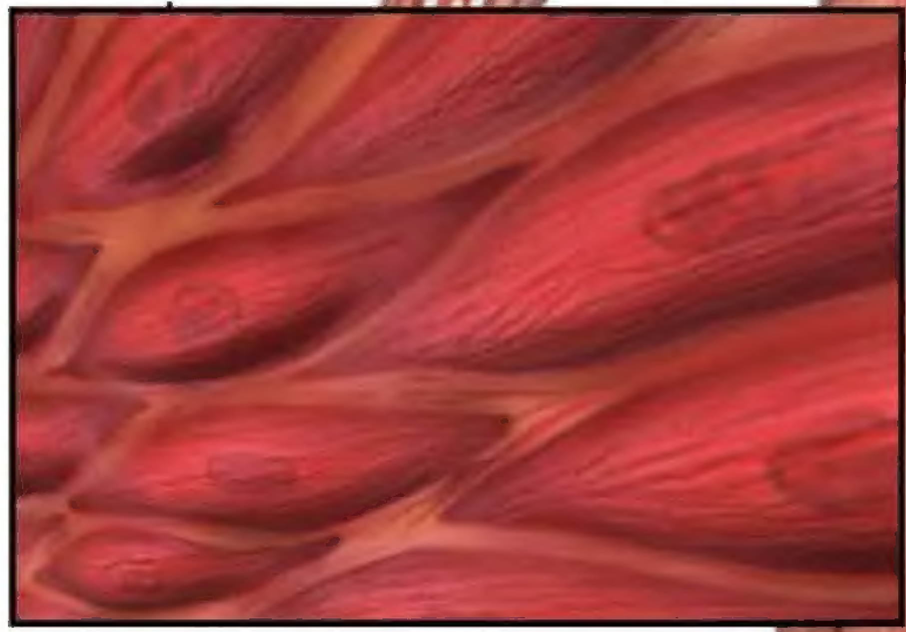




Cardiac muscle
Type: Heart
Like skeletal muscle, cardiac muscle is striated. Connections between the cells allow the contraction to pass in a co-ordinated wave across the heart.

Skeletal muscle
Type: Voluntary
Skeletal muscle is responsible for moving the skeleton. Under the microscope it has characteristic striped bands, representing the contractile components within the cells.

Smooth muscle
Type: Involuntary
The smooth muscle that lines internal structures is more elastic than skeletal muscle, allowing the intestines and bladder, etc, to contract even when stretched.



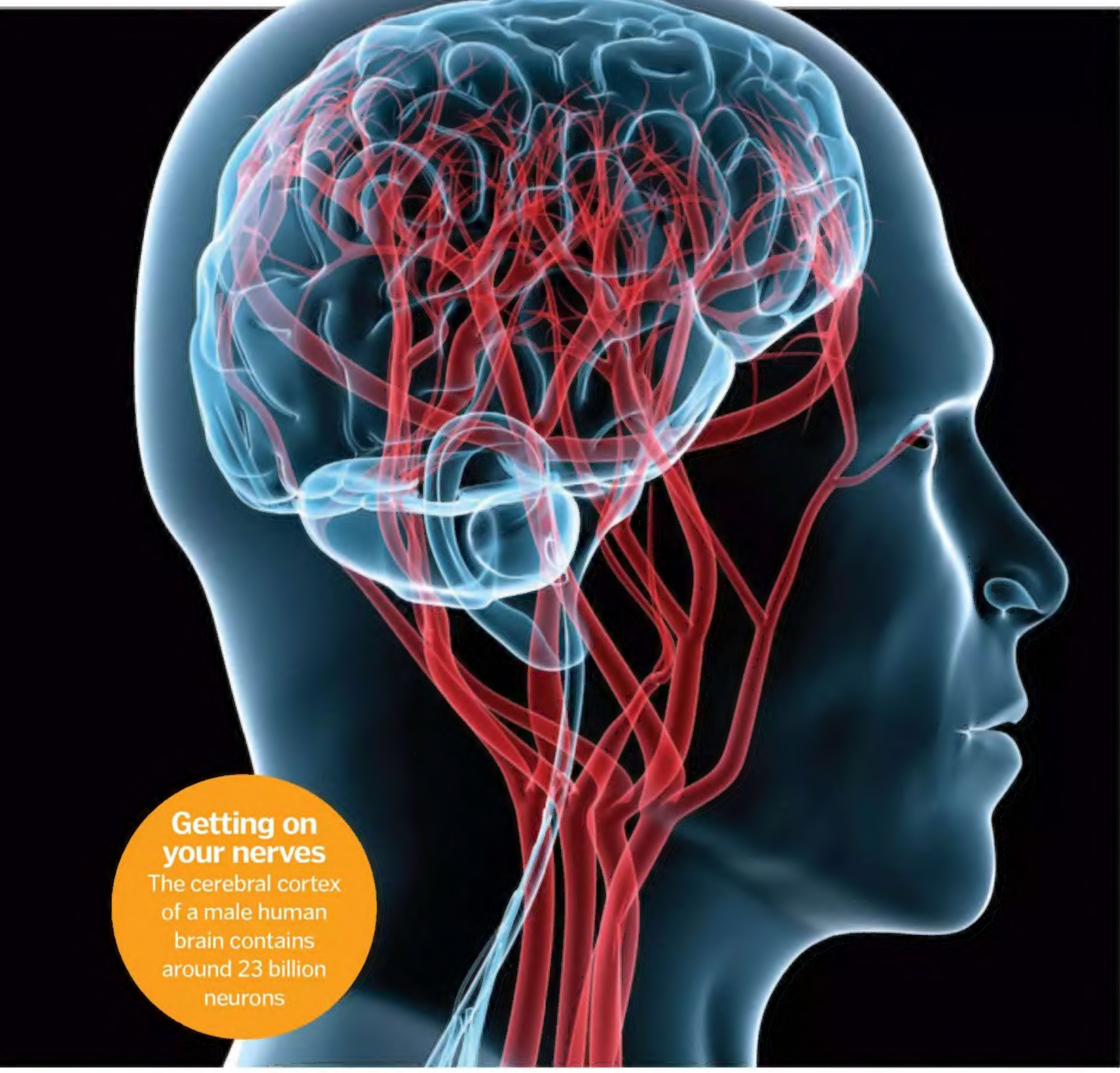
Why our bodies need a little fat

Adipose tissue provides the body with an energy reserve and also acts as a shock absorber – particularly on the soles of the feet. The fat cells – also known as adipocytes – contain a large lipid droplet, which takes up almost their entire volume, while their nuclei and other organelles are squashed on the perimeter.

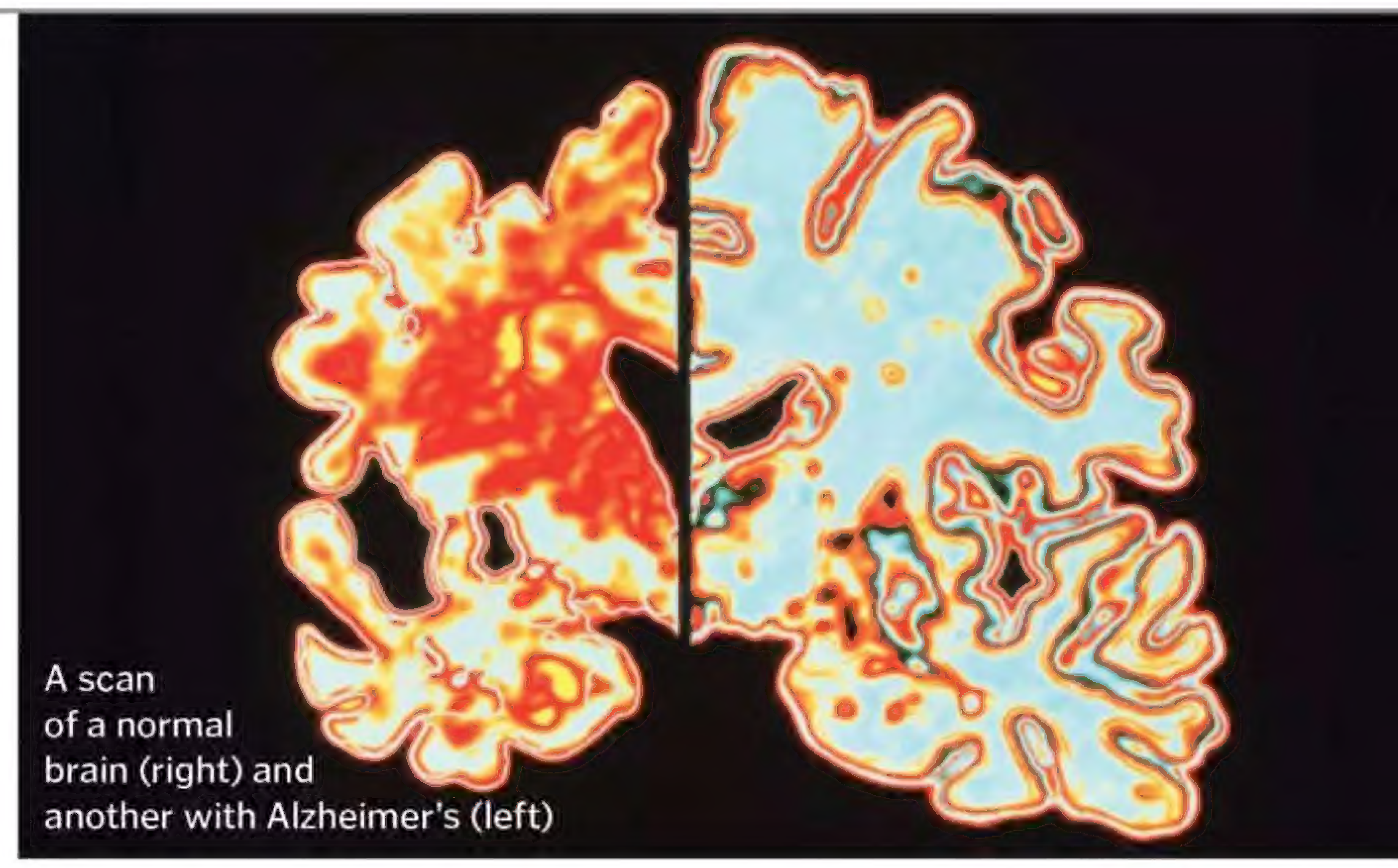
Adipocytes are not just used as storage sacks though; they have important metabolic and hormonal duties too, including involvement in the production of oestrogen.

Humans have a second type of fat tissue known as 'brown fat'. More commonly found in infants, brown fat provides a thermal blanket around the neck and the major blood vessels in the thorax. Brown fat cells are able to generate heat by a method known as uncoupling; instead of using glucose to make energy for the cell in the form of ATP, the brown fat can release the energy as heat. This is thought to be very important in newborns, who lack the ability to keep warm by shivering.

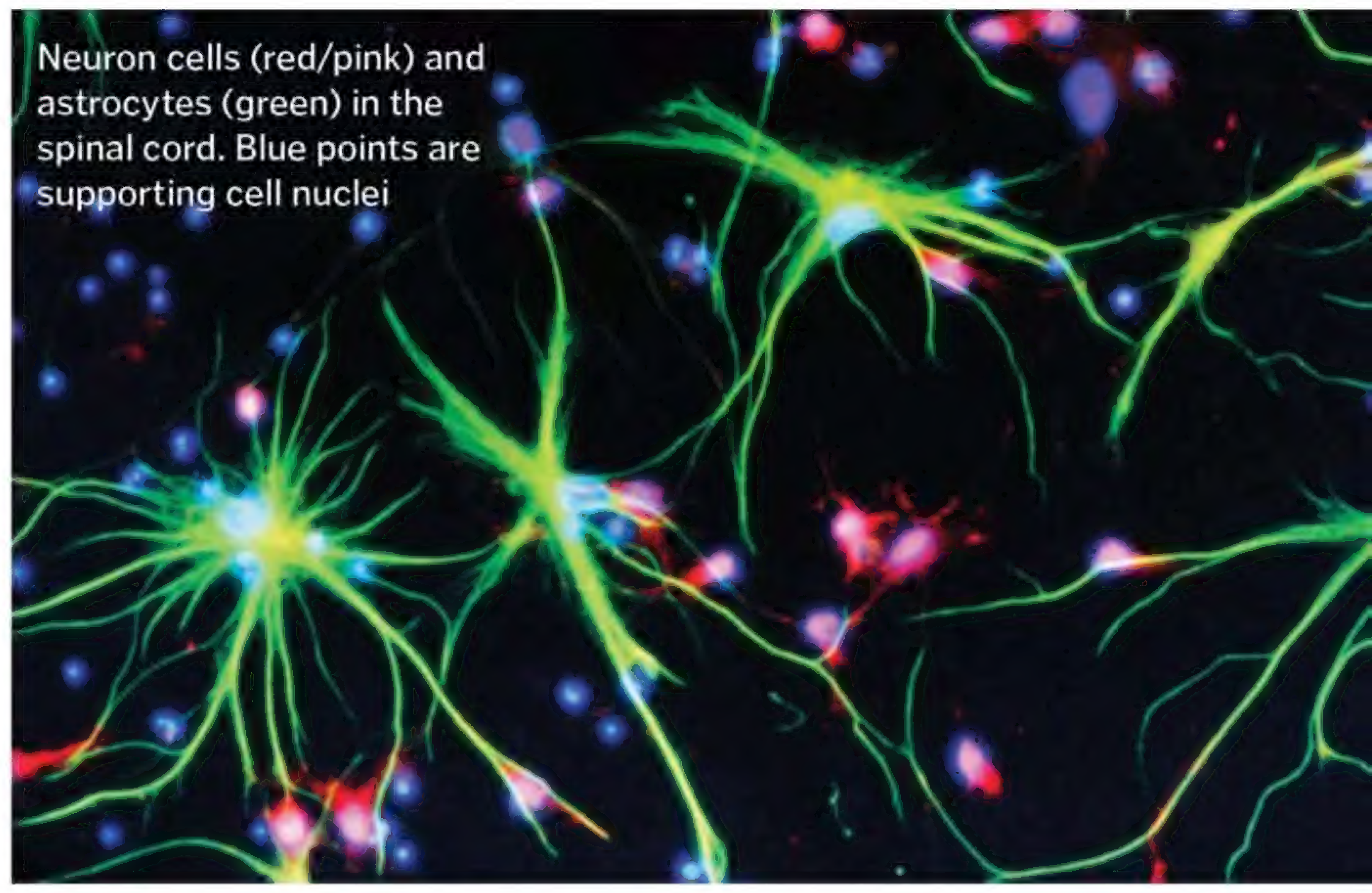
A fatty fact
The average human adult will have 30 billion fat cells



Getting on your nerves
The cerebral cortex of a male human brain contains around 23 billion neurons



A scan of a normal brain (right) and another with Alzheimer's (left)



Neuron cells (red/pink) and astrocytes (green) in the spinal cord. Blue points are supporting cell nuclei

Inside the brain

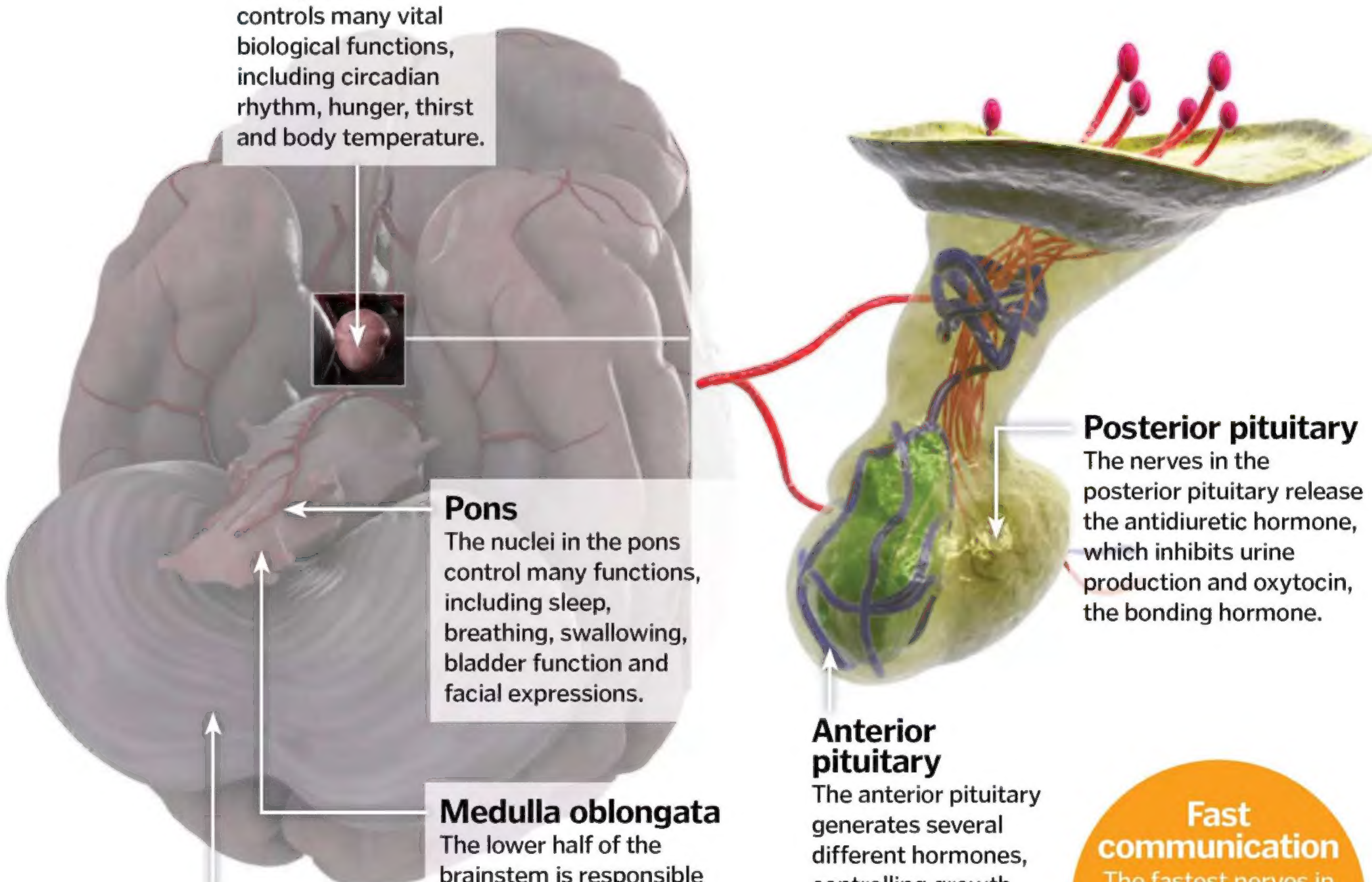
The brain is made up of two major types of cells: neurons and glial cells.

The neurons of the brain are highly specialised cells, interconnected by long, branching processes. They communicate through electrical 'action potentials', which can travel along the axons at speeds of 1-100 metres (3.3-328 feet) per second.

When an action potential reaches the synapse at the end of a nerve, it triggers the release of chemical transmitters, which bind to receptors on neighbouring nerves. Depending on the combination of neurotransmitters released – and the timing – the target nerve will fire, propagating the signal through the brain.

Glial cells, on the other hand, provide support to the neurons and have a variety of specialist functions. Astrocytes help to take up excess neurotransmitters from synapses, preventing neurons from damage due to excessive stimulation, while oligodendrocytes form fatty sheaths in order to insulate nerve cells in the brain and spinal cord.

The brain has significantly more protection than the other organs of the body. It is shielded from mechanical stress by the thick bones of the skull and is suspended in a cushion of cerebrospinal fluid. At the microscopic level, the brain is protected from potential hazards in the bloodstream by the blood-brain barrier – the cells lining the capillaries are joined together by tight junctions, controlling the passage of all molecules and bacteria into the organ.



Hypothalamus
The hypothalamus controls many vital biological functions, including circadian rhythm, hunger, thirst and body temperature.

Pons
The nuclei in the pons control many functions, including sleep, breathing, swallowing, bladder function and facial expressions.

Posterior pituitary
The nerves in the posterior pituitary release the antidiuretic hormone, which inhibits urine production and oxytocin, the bonding hormone.

Anterior pituitary
The anterior pituitary generates several different hormones, controlling growth, thyroid function, fertility and stress.

Medulla oblongata
The lower half of the brainstem is responsible for controlling fundamental involuntary functions like breathing and heartbeat.

Cerebellum
The cerebellum has an important role in the co-ordination and timing of movement.

Fast communication
The fastest nerves in the body can transmit electrical signals at 120m (394ft) per second

DID YOU KNOW? *The red colour of blood isn't due to iron, but the shape of the porphyrin molecule that contains it*

What role do hormones play in the body?

Angiotensin
Produced: Liver
Angiotensin causes blood vessels to constrict, raising blood pressure. ACE inhibitors that treat high blood pressure inhibit its activity.

Erythropoietin
Produced: Kidney
Cells in the kidney are sensitive to blood oxygen levels and can release this hormone to encourage production of new red blood cells.

Ghrelin
Produced: Stomach
A chemical signal produced mainly by the stomach. It acts as an appetite stimulant, making you feel both hungry or full up.

Oxytocin
Produced: Mainly in the brain
This is also known as the 'bonding hormone' and is produced at high levels during and after childbirth.

Cortisol
Produced: Adrenal glands
The 'stress hormone' helps to increase blood sugar by promoting the breakdown of fat and muscle tissue.

Leptin
Produced: Fat
Made by fat tissue, leptin plays a fundamental role in acting as a fuel gauge and telling the brain just how much fat is stored in the body.

The ageing body

The human body changes as it ages and the peak time for organ functionality is thought to be around the age of 30. The body has amazing capacity for regeneration, but cells can only divide a finite number of times, and as we get older our ability to repair damaged tissue decreases.

Dramatic changes, such as the menopause, produce obvious effects on the body. Female sex hormones are not just involved in reproduction, but also play a role in other processes, such as the maintenance of bone density. In the absence of oestrogen, bone mineral density decreases, which can lead to osteoporosis. A similar, but less dramatic, effect can be seen in men as testosterone levels begin to drop.

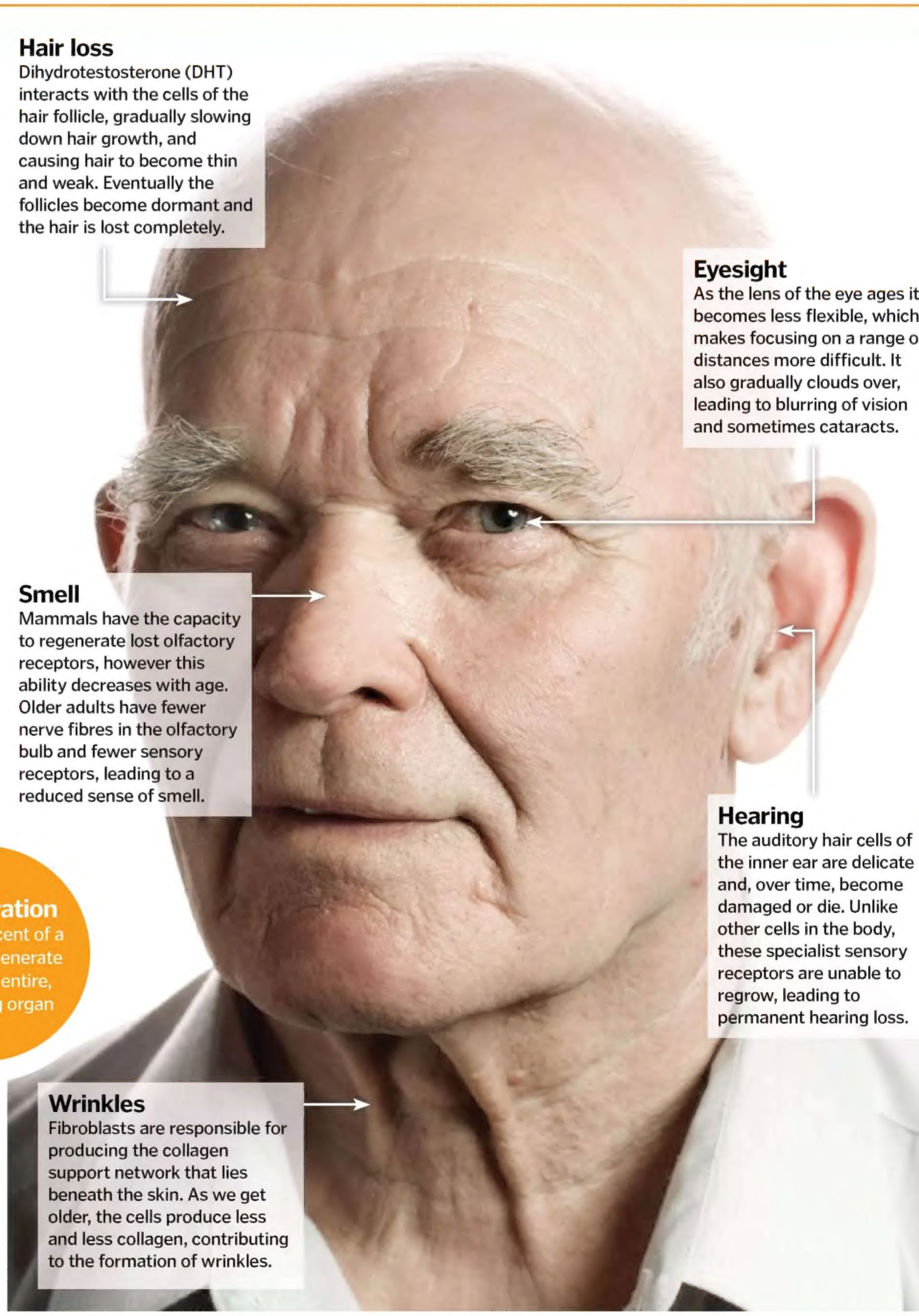
Similar decline in functionality can be observed throughout the human body; collagen in the skin begins to decrease, insulated axons in the brain shorten, and DNA damage accumulates, leading to an ever greater risk of cancer.

However, it's not all bad. Life expectancy is on the increase, and scientists are coming closer to understanding – and being able to slow – the complex processes of human ageing.

As the body gets older it becomes more susceptible to faulty cells that cause cancer

Arthritis is the main cause of disability in over-55s in industrialised countries

Regeneration
Just 25 per cent of a liver can regenerate to form an entire, functioning organ



Hair loss
Dihydrotestosterone (DHT) interacts with the cells of the hair follicle, gradually slowing down hair growth, and causing hair to become thin and weak. Eventually the follicles become dormant and the hair is lost completely.

Eyesight
As the lens of the eye ages it becomes less flexible, which makes focusing on a range of distances more difficult. It also gradually clouds over, leading to blurring of vision and sometimes cataracts.

Smell
Mammals have the capacity to regenerate lost olfactory receptors, however this ability decreases with age. Older adults have fewer nerve fibres in the olfactory bulb and fewer sensory receptors, leading to a reduced sense of smell.

Hearing
The auditory hair cells of the inner ear are delicate and, over time, become damaged or die. Unlike other cells in the body, these specialist sensory receptors are unable to regrow, leading to permanent hearing loss.

Wrinkles
Fibroblasts are responsible for producing the collagen support network that lies beneath the skin. As we get older, the cells produce less and less collagen, contributing to the formation of wrinkles.

How the human skeleton works

Without a skeleton, we would not be able to live. It is what gives us our shape and structure and its presence allows us to operate on a daily basis. It also is a fascinating evolutionary link to all other living and extinct vertebrates

The human skeleton is crucial for us to live. It keeps our shape and muscle attached to the skeleton allows us the ability to move around, while also protecting crucial organs that we need to survive. Bones also produce blood cells within bone marrow and store minerals we need released on a daily basis.

As a fully grown adult you will have around 206 bones, but you are born with over 270, which continue to grow, strengthen and fuse after birth until around 18 in females and 20 in males. Human skeletons actually do vary between sexes in structure also. One of the most obvious areas is the pelvis as a female must be able to give birth, and therefore hips are comparatively shallower and wider. The cranium also becomes more robust in males due to heavy muscle attachment and a male's chin is often more prominent. Female skeletons are generally more delicate overall. However, although there are several methods, sexing can be difficult because of the level of variation we see within the species.

Bones are made up of various different elements. In utero, the skeleton takes shape as cartilage, which then starts to calcify and develop during gestation and following birth. The primary element that makes up bone, osseous tissue, is actually mineralised calcium phosphate, but other forms of tissue such as marrow, cartilage and blood vessels are also contained in the overall structure. Many individuals think that bones are solid, but actually inner bone is porous and full of little holes.

As we age, so do our bones. Even though cells are constantly being replaced, and therefore no cell in our body is more than 20 years old, they are not replaced with perfect, brand-new cells. The cells contain errors in their DNA and ultimately our bones therefore weaken as we age. Conditions such as arthritis and osteoporosis can often be caused by ageing and cause issues with weakening of bones and reduced movement ability.

4. Radius/Ulna
The radius and ulna are the bones situated in the forearm. They connect the wrist and the elbow.

5. Rib cage
This structure of many single rib bones creates a protective barrier for organs situated in the chest cavity. They join to the vertebrae in the spine at the back of the body, and the sternum at the front.

1. Snails
Exoskeletons are often seen in animals. These are bulky, tough outer layers that protect the individual, instead of the endoskeletons we have.

2. Snake
The skeleton of a snake is one of the strangest. Because of how it moves, it has more joints in the body, primarily vertebrae, and has no limbs.

3. Giraffe
Considering the size of a giraffe's neck, you'd expect it to have more cervical vertebrae than a human, but it only has seven – the same as us!

DID YOU KNOW? *Around five per cent of all animals have backbones and are therefore classified as vertebrates*

Inside our skeleton

How the human skeleton works and keeps us upright

1. Cranium
The cranium, also known as the skull, is where the brain and the majority of the sensory organs are located.

2. Metacarpals
The long bones in the hands are called metacarpals, and are the equivalent of metatarsals in the foot. Phalanges located close to the metacarpals make up the fingers.

3. Vertebrae
There are three main kinds of vertebrae (excluding the sacrum and coccyx) – cervical, thoracic and lumbar. These vary in strength and structure as they carry different pressure within the spine.

6. Pelvis
This is the transitional joint between the trunk of the body and the legs. It is one of the key areas in which we can see the skeletal differences between the sexes.

7. Femur
This is the largest and longest single bone in the body. It connects to the pelvis with a ball and socket joint.

8. Fibula/Tibia
These two bones form the lower leg bone and connect to the knee joint and the foot.

9. Metatarsals
These are the five long bones in the foot that aid balance and movement. Phalanges located close to the metatarsals are the bones which are present in toes.

Breaking bones

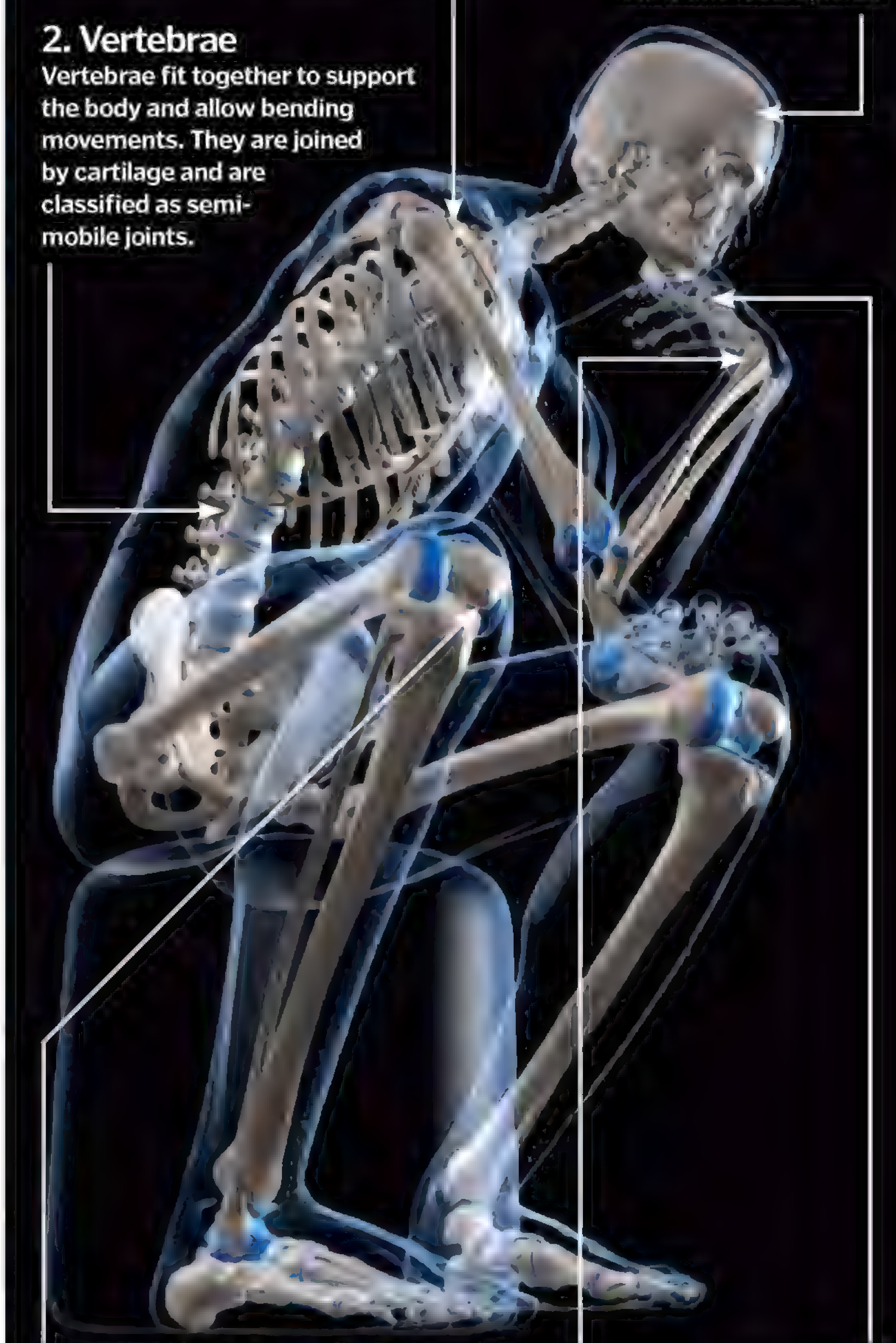
Whether it's a complete break or just a fracture, both can take time to heal properly

If you simply fracture the bone, you may just need to keep it straight and keep pressure off it until it heals. However, if you break it into more than one piece, you may need metal pins inserted into the bone to realign it or plates to cover the break in order for it to heal properly. The bone heals by producing new cells and tiny blood vessels where the fracture or break has occurred and these then rejoin up. For most breaks or fractures, a cast external to the body will be put on around the bone to take pressure off the bone to ensure that no more damage is done and the break can heal.

A typical cast for when someone has managed to break a bone. Unbelievably, a saw is the method of choice for removal!

How our joints work

The types of joints in our body explained



1. Ball and socket joints
Both the hip and the shoulder joints are ball and socket joints. The femur and humerus have ball shaped endings, which turn in a cavity to allow movement.

2. Vertebrae
Vertebrae fit together to support the body and allow bending movements. They are joined by cartilage and are classified as semi-mobile joints.

3. Skull sutures
Although not generally thought of as a 'joint', all the cranial sutures present from where bones have fused in childhood are in fact immoveable joints.

4. Hinged joints
Both elbows and knees are hinged joints. These joints only allow limited movement in one direction. The bones fit together and are moved by muscles.

5. Gliding joints
Some movement can be allowed when flat bones 'glide' across each other. The wrist bones – the carpals – operate like this, moved by ligaments.

6. Saddle joints
The only place we see this joint in humans is the thumb. Movement is limited in rotation, but the thumb can move back, forward and to the sides.

Skull development

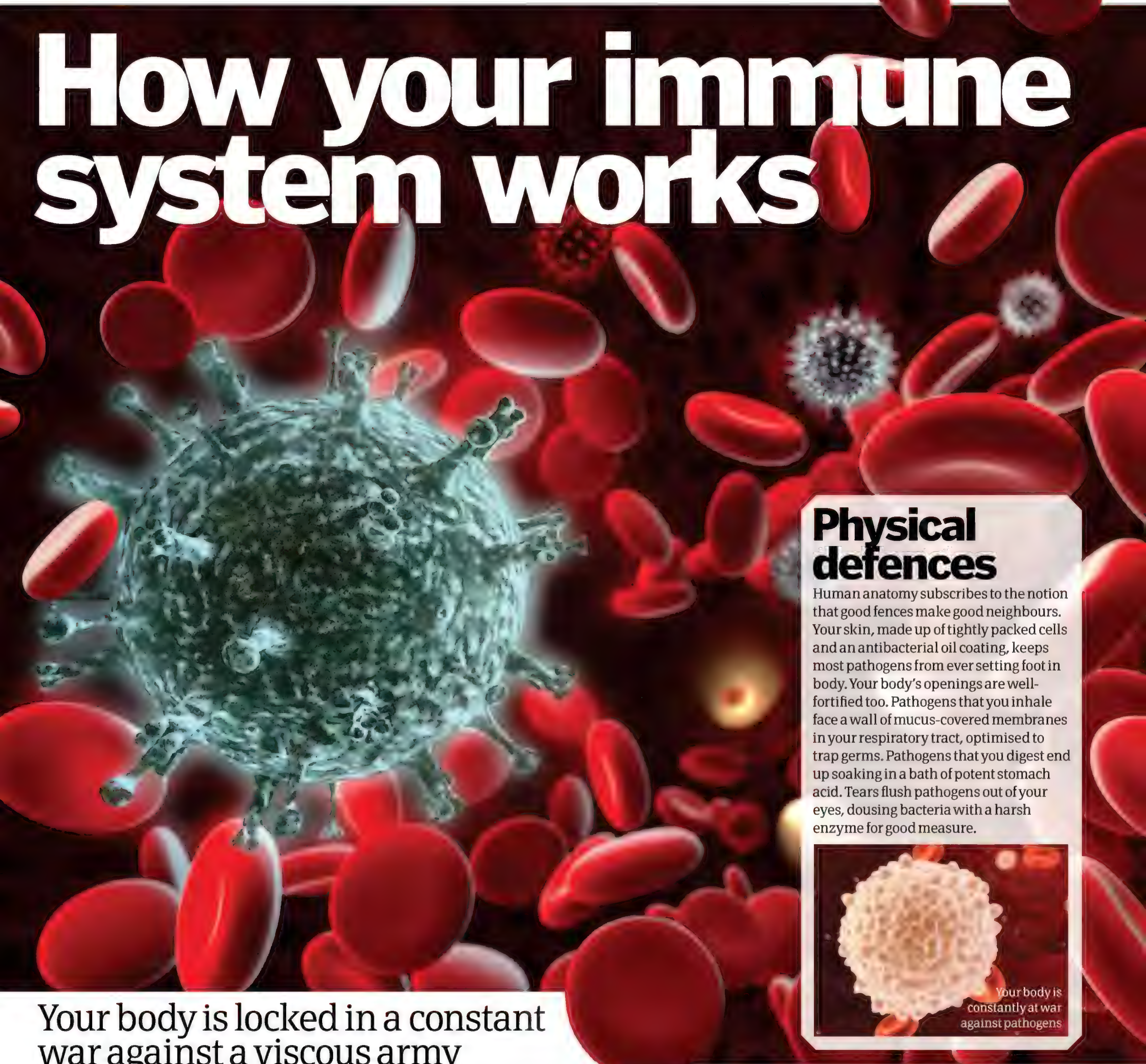
When we are born, many of our bones are still somewhat soft and are not yet fused – this process occurs later during our childhood

The primary reasons for the cranium in particular not to be fully fused at birth is to allow the skull to flex as the baby is born and also to allow the extreme rate of growth that occurs in the first few years of childhood following birth. The skull is actually in seven separate plates when we are born and over the first two years these pieces fuse together slowly and ossify. The plates start suturing together early on, but the anterior fontanel – commonly known as the soft spot – will take around 18 months to fully heal. Some other bones, such as the five bones located in the sacrum, don't fully fuse until late teens or early twenties, but the cranium becomes fully fused by around age two.

3 skulls © DK Images

"Dangerous bacteria release toxins in the body that cause diseases"

How your immune system works



Physical defences

Human anatomy subscribes to the notion that good fences make good neighbours. Your skin, made up of tightly packed cells and an antibacterial oil coating, keeps most pathogens from ever setting foot in body. Your body's openings are well-fortified too. Pathogens that you inhale face a wall of mucus-covered membranes in your respiratory tract, optimised to trap germs. Pathogens that you digest end up soaking in a bath of potent stomach acid. Tears flush pathogens out of your eyes, dousing bacteria with a harsh enzyme for good measure.

Your body is constantly at war against pathogens

Your body is locked in a constant war against a viscous army

It's true: while you're sitting around watching TV, trillions of foreign invaders are launching a full scale assault on the trillions of cells that constitute 'you'. Collectively known as pathogens, these attackers include bacteria, single-celled creatures that live to eat and reproduce; protists, larger single-cell organisms; viruses, packets of genetic information that take over host cells and replicate inside them; and fungi, a type of plant life.

Bacteria and viruses are by far the very worst offenders. Dangerous bacteria release toxins in the body that cause diseases such as E. coli, anthrax, and the black plague. The cell damage from viruses causes measles, the flu and the common cold, among numerous other diseases.

Just about everything in our environment is teeming with these microscopic intruders... including you. The bacteria in your stomach alone outnumber all the cells in your body, ten-to-one. Yet, your scrappy microscopic soldiers usually win the day against pathogens, through a combination of sturdy barriers, brute force, and superior battlefield intelligence, collectively dubbed the immune system.

5 TOP FACTS IMMUNE SYSTEM

The cure can sometimes hurt

1 Sneezing, coughing, a sore throat, and fever are all means of expelling pathogens, so as annoying as they are, each one is necessary.

Immunity soldiers are everywhere

2 A single drop of blood contains around 375,000 white blood cells, and blood constitutes for seven per cent of your total body weight.

You can 'borrow' immunity

3 Antibodies in breast milk give babies temporary immunity from diseases their mother is immune to, preventing infancy infection.

It deals with internal troubles, too

4 In addition to fighting pathogens, T-cells fight the body's own cancerous cells and some cancer therapies boost the number of T-cells.

It has trouble with change

5 Unfortunately you cannot develop immunity to the flu and common cold because the viruses are always mutating.

DID YOU KNOW? *Dr Karl Landsteiner first identified the major human blood groups – A, B, AB and O – in 1901*

The adaptive immune system

Fighting the good fight, and white blood cells are right on the front line…

When a pathogen is tough, wily, or numerous enough to survive non-specific defences, it's up to the adaptive immune system to clean up the mess. The key forces in the adaptive immune system are white blood cells called lymphocytes. Unlike their macrophage cousins, lymphocytes are engineered to attack only one specific type of pathogen. There are two types of lymphocytes: B-cells and T-cells.

These cells join the action when macrophages pass along information about the invading pathogen, through chemical messages called interleukins. After engulfing a pathogen, a macrophage communicates details about the pathogen's antigens – telltale molecules that characterise a particular pathogen. Based on this information, the immune system identifies specific B-cells and T-cells equipped to recognise and battle the pathogen. Once they are successfully identified, these cells rapidly reproduce, assembling an army of cells that are ready and equipped to take down the attacker.

The B-cells flood your body with antibodies, molecules that either disarm a specific pathogen or bind to it, marking it as a target for other white blood cells. When T-cells find their target, they lock on and release toxic chemicals that will destroy it. T-cells are especially adept at destroying your body's cells that are infected with a virus.

This entire process takes several days to get going and may take even longer to conclude. All the while, the raging battle can make you feel terrible. Fortunately, the immune system is engineered to learn from the past. While your body is producing new B-cells and T-cells to fight the pathogens, it also produces memory cells – copies of the B-cells and T-cells, which stay in the system after the pathogen is defeated. The next time that pathogen shows up in your body, these memory cells help launch a counter-attack much more quickly. Your body can wipe out the invaders before any infection takes hold. In other words, you develop immunity.

Vaccines accomplish the same thing by giving you just enough pathogen exposure for you to develop memory cells, but not enough to make you sick.

Does your immune system cut the mustard?

Non-specific defences

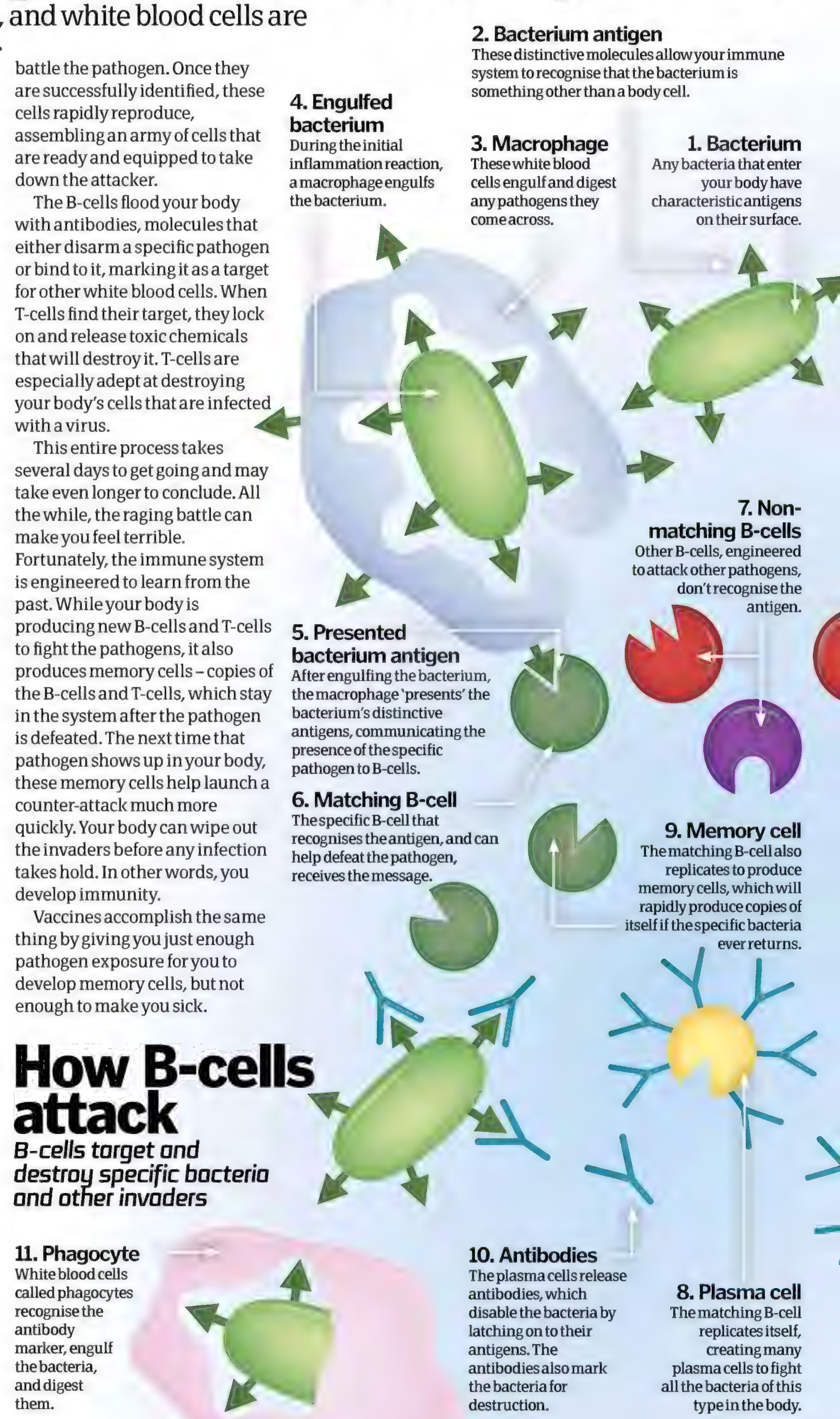
As good as your physical defence system is, pathogens do creep past it regularly. Your body initially responds with counterattacks known as non-specific defences, so named because they don't target a specific type of pathogen.

After a breech – bacteria rushing in through a cut, for example – cells release chemicals called inflammatory mediators. This triggers the chief non-specific defence, known as inflammation. Within minutes of a breach, your blood vessels dilate, allowing blood and other fluid to flow into the tissue around the cut.

The rush of fluid in inflammation carries various types of white blood cells, which get to work destroying intruders. The biggest and toughest of the bunch are macrophages, white blood cells with an insatiable appetite for foreign particles. When a macrophage detects a bacterium's telltale chemical trail, it grabs the intruder, engulfs it, takes it apart with chemical enzymes, and spits out the indigestible parts. A single macrophage can swallow up about 100 bacteria before its own digestive chemicals destroy it from within.

How B-cells attack

B-cells target and destroy specific bacteria and other invaders



Anyone fancy meatballs for dinner?

Disorders of the immune system

Who watches the watchmen?

The immune system is a powerful set of defences, so when it malfunctions, it can do as much harm as a disease. Allergies are the result of an overzealous immune system. In response to something relatively benign, like pollen, the immune system triggers excessive measures to expel the pathogen. On the extreme end, allergies may cause anaphylactic shock, a potentially deadly drop in blood pressure, sometimes accompanied by breathing difficulty and loss of consciousness. In autoimmune disorders such as rheumatoid arthritis, the immune system fails to recognise the body's own cells and attacks them.

In an allergic reaction, the body may resort to sneezing to expel a fairly harmless pathogen

In rheumatoid arthritis, the immune system attacks joint linings

The lymphatic system

The lymphatic system is a network of organs and vessels that collects lymph – fluid that has drained from the bloodstream into bodily tissues – and returns it to your bloodstream. It also plays a key role in your immune system, filtering pathogens from lymph and providing a home-base for disease-fighting lymphocytes.

1. Tonsils
Lymphoid tissue loaded with lymphocytes, which attack bacteria that get into the body through your nose or mouth.

2. Left subclavian vein
One of two large veins that serve as the re-entry point for lymph returning to the bloodstream.

3. Right lymphatic duct
Passageway leading from lymph vessels to the right subclavian vein.

4. Right subclavian vein
The second of the two subclavian veins, this one taking the opposite path to its twin.

5. Spleen
An organ that houses white blood cells that attack pathogens in the bloodstream.

6. Lymph node cluster
Located along lymph vessels throughout the body, lymph nodes filter lymph as it makes its way back into the bloodstream.

7. Left lymphatic duct
Passageway leading from lymph vessels to the left subclavian vein.

8. Thymus gland
Organ that provides area for lymphocytes produced by bone marrow to mature into specialised T-cells.

9. Thoracic duct
The largest lymph vessel in the body.

10. Lymph vessels
Lymph collects in tiny capillaries, which expand into larger vessels. Skeletal muscles move lymph through these vessels, back into the bloodstream.

11. Peyer's patch
Nodules of lymphoid tissue supporting white blood cells that battle pathogens in the intestinal tract.

12. Bone marrow
The site of all white blood cell production.

© DK Images

© Ed Uthman, MD

Lymph nodes explained

Lymph nodes filter out pathogens moving through your lymph vessels

Your immune system depends on these .04-1-inch swellings to fight all manner of pathogens. As lymph makes its way through a network of fibres in the node, white blood cells filter it, destroying any pathogens they find.

1. Influenza
The flu kills hundreds of thousands of people in a good year. And every once in a while, a virulent form can take out tens of millions.

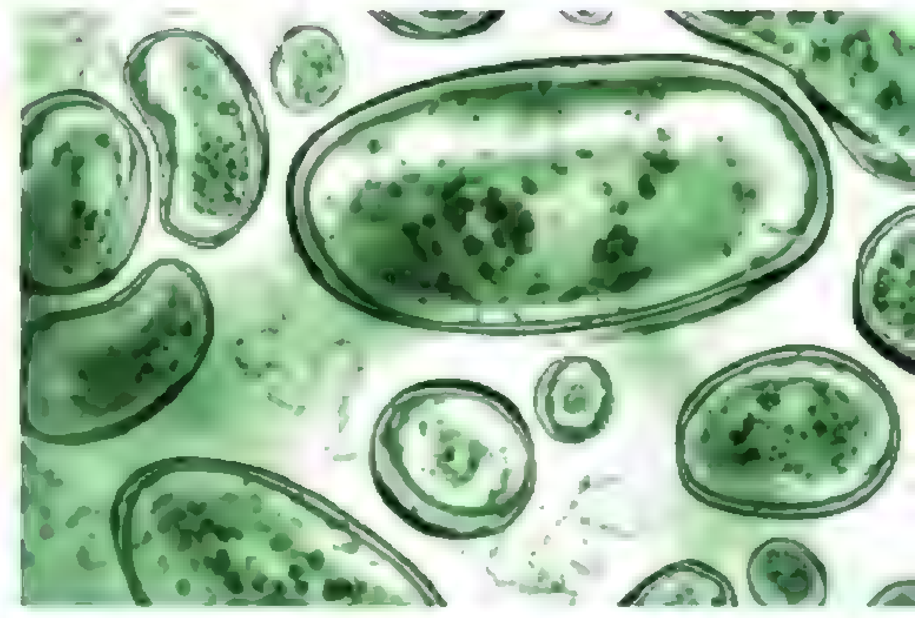
2. Measles
One person infected with measles will spread the virus to just about every unvaccinated person they encounter. Luckily, the vaccine is very effective.

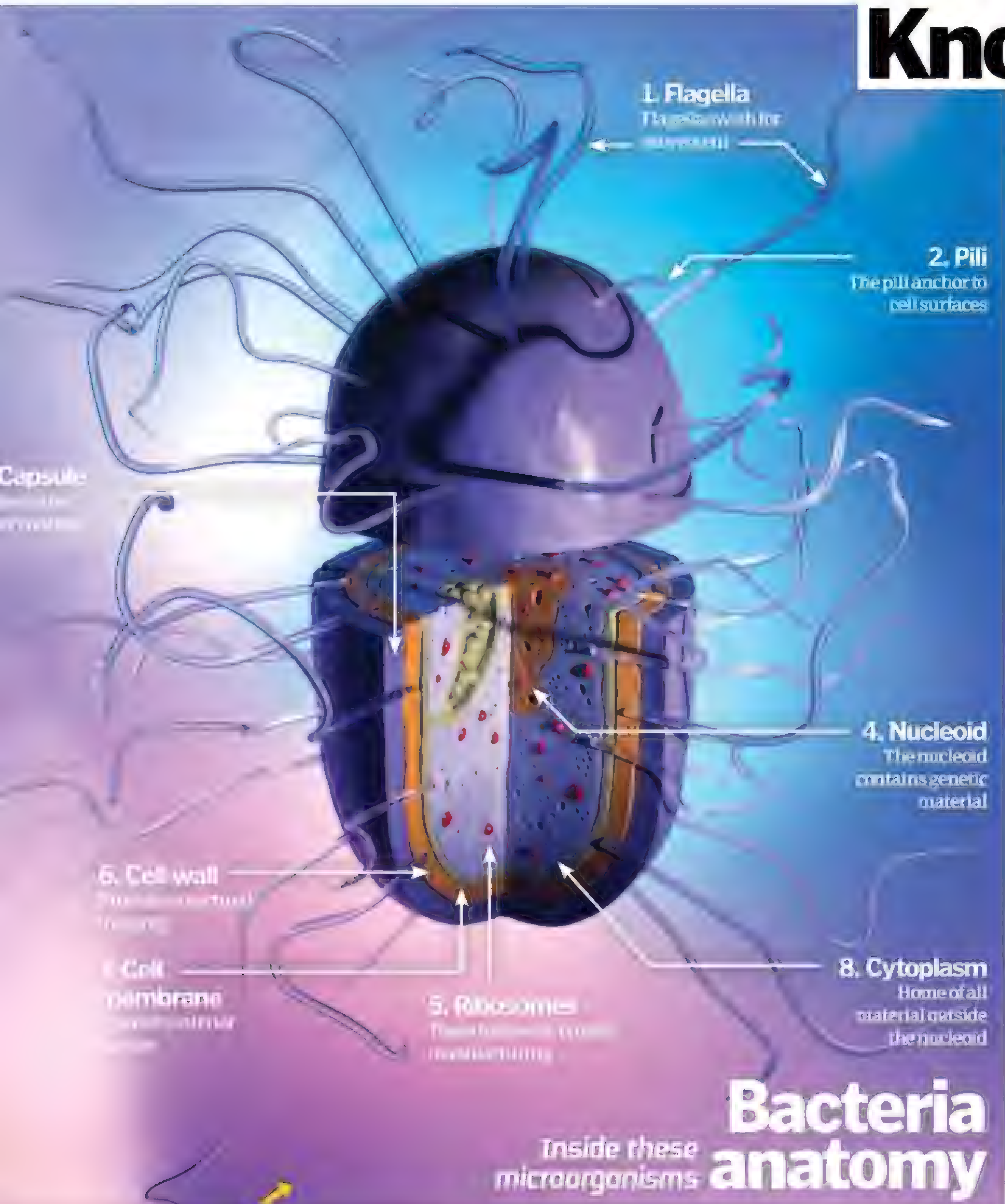
3. Tuberculosis
Ancient Egyptian mummies show signs of tuberculosis, and the disease is still thriving today. Around 2 billion people are infected.

DID YOU KNOW? In 2008, approximately 33 million people worldwide were living with HIV or AIDS

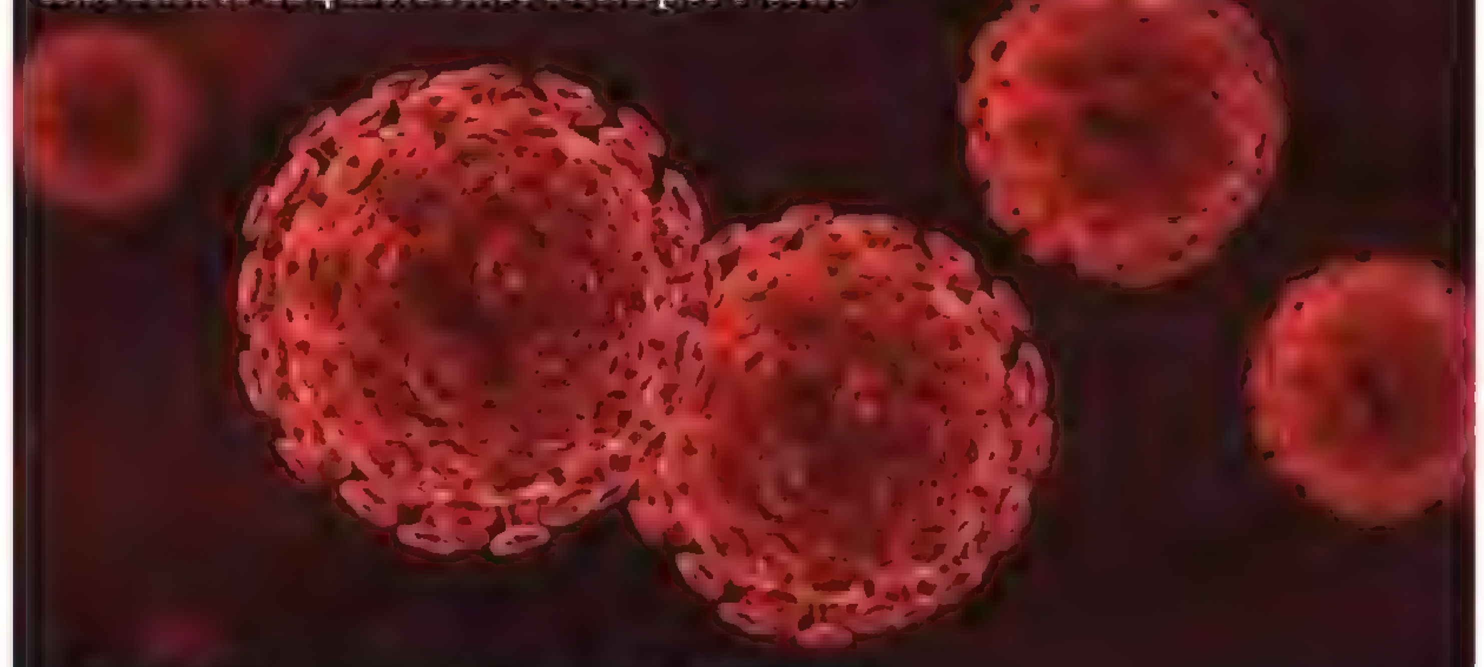
Know your enemy: Bacteria

Bacteria are the smallest and, by far, the most populous form of life on Earth. Right now, there are trillions of the single-celled creatures crawling on and in you. In fact, they constitute about four pounds of your total body weight. To the left is a look at bacteria anatomy…





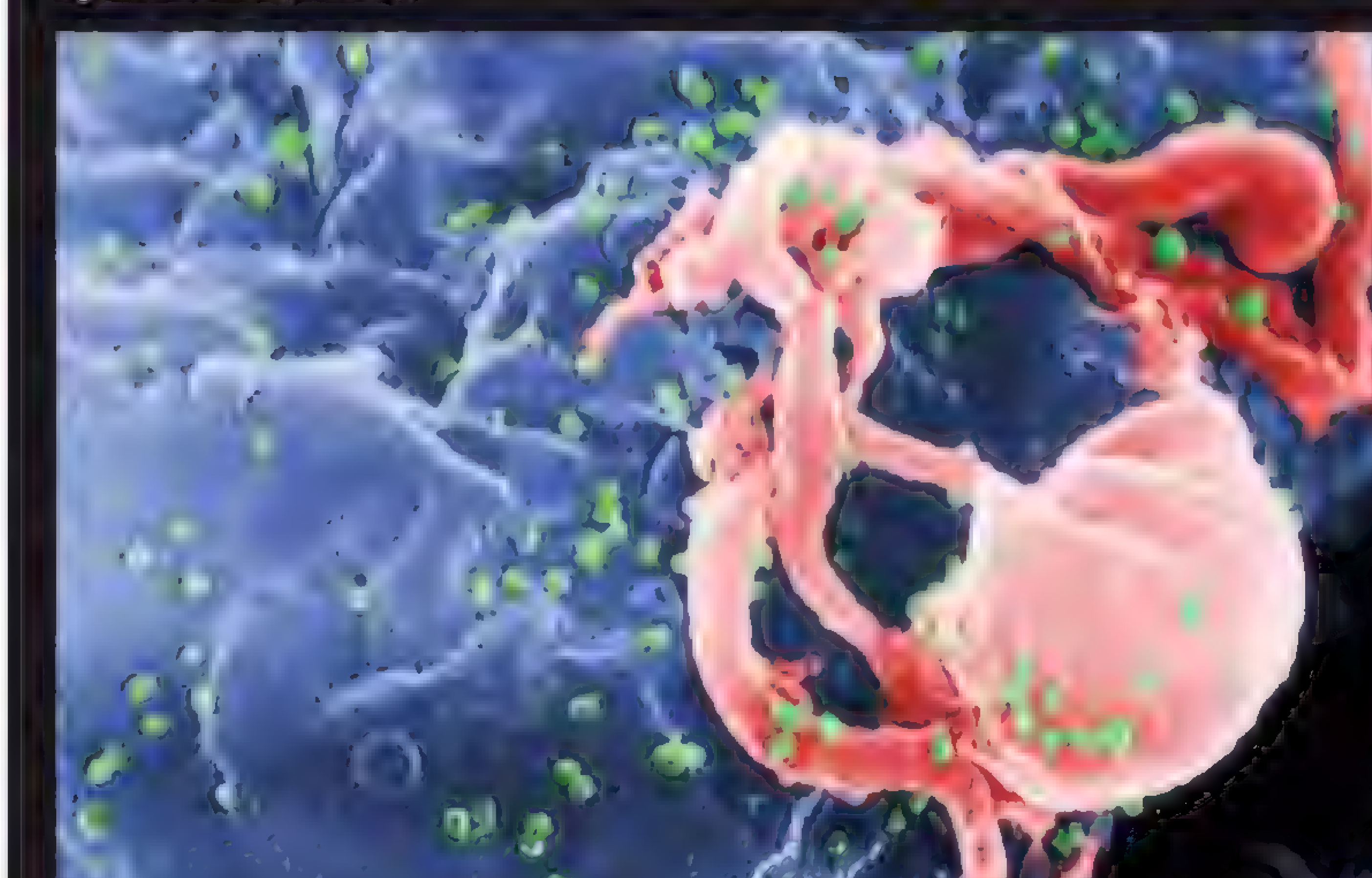
Free HIV particles, with protruding antigens that bind to CD4 molecules on helper T-cells



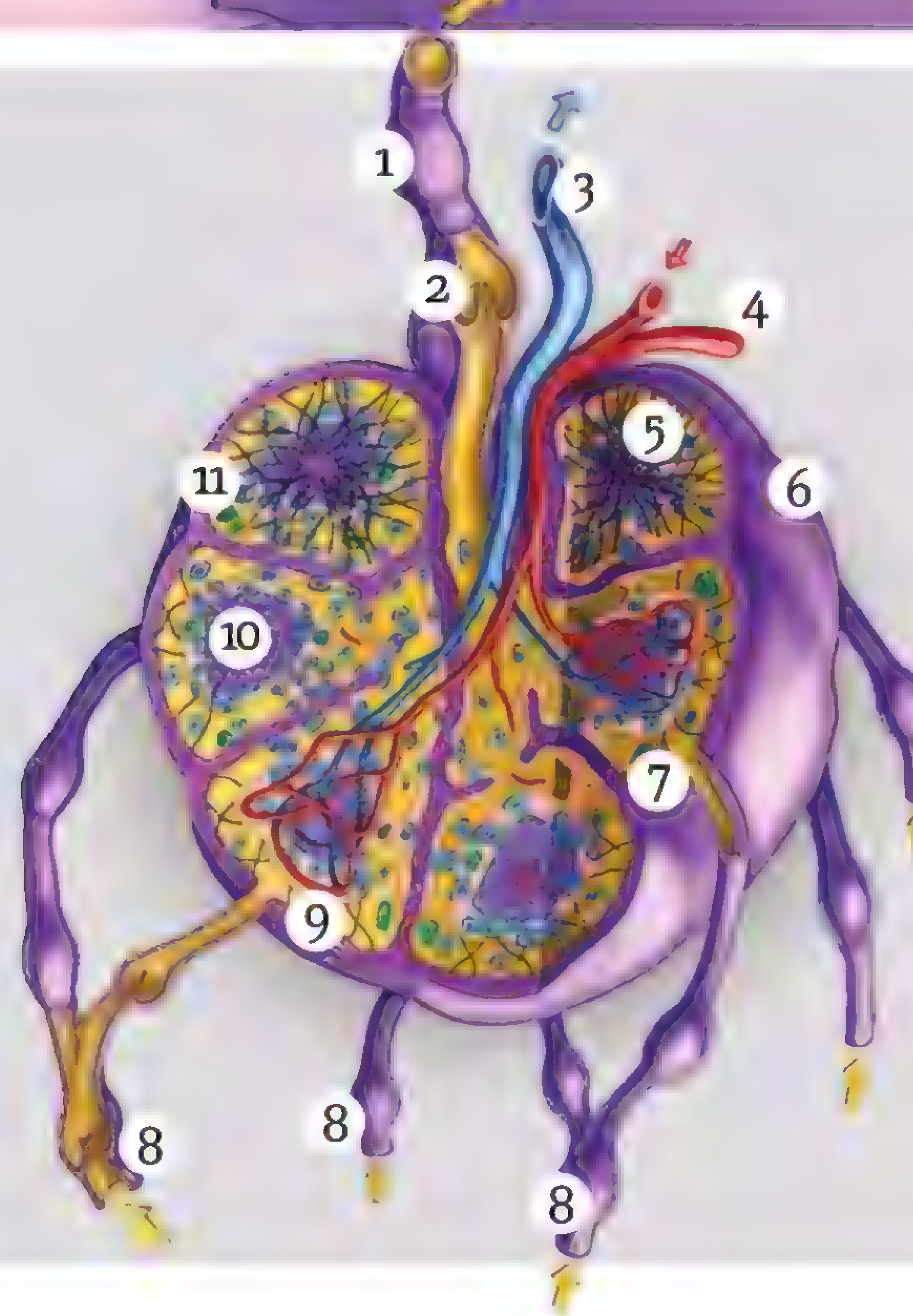
What is HIV…

… and how does it affect the immune system?

The human immunodeficiency virus (HIV) is a retrovirus (a virus carrying ribonucleic acid, or RNA as it's known), transmitted through bodily fluids. Like other deadly viruses, HIV invades cells and multiplies rapidly inside. Specifically, HIV infects cells with CD4 molecules on their surface, which includes infection-fighting helper T-cells. HIV destroys the host cell, and the virus copies go on to infect other cells. As the virus destroys helper T-cells, it steadily weakens the immune system. If enough T-cells are lost, the body becomes highly susceptible to a range of infections, a condition known as acquired immune deficiency syndrome (AIDS).



Scanning electron micrograph of HIV-1 budding (in green) from cultured lymphocyte. This image has been coloured to highlight the most important features. Multiple round bumps on the cell surface represent sites of assembly and budding of virions.



Major points of the lymph node

1. Outgoing lymph vessel
The vessel that carries filtered lymph out of the lymph node

2. Valve
A structure that prevents lymph from flowing back into the lymph node

3. Vein
Passageway for blood leaving the lymph node

4. Artery
Supply of incoming blood for the lymph node

5. Reticular fibres
Divides the lymph node into individual cells

6. Capsule
The protective fibres surrounding the lymph node

7. Sinus
A channel that slows the flow of lymph, giving macrophages the opportunity to destroy pathogens

8. Incoming lymph vessel
A vessel that carries lymph into the lymph node

9. Lymphocyte
The T-cells, B-cells and natural killer cells that fight infection

10. Germinal centre
Site of lymphocyte multiplication and maturation

11. Macrophage
Large white blood cells that engulf and destroy pathogens

The heart – a vital organ

Your heart is a turbocharged double-pumping muscle that beats more than 40 million times every year

Not only does your heart do amazing things, it does so tirelessly, every minute of every day from the moment you're born (actually, even a bit before then) to the instant that you die. It weighs somewhere between eight and 12 ounces – slightly more if you're male, less if you're female. Its sole purpose is to push blood through your circulatory system, providing crucial oxygen and other nutrients to all your organs.

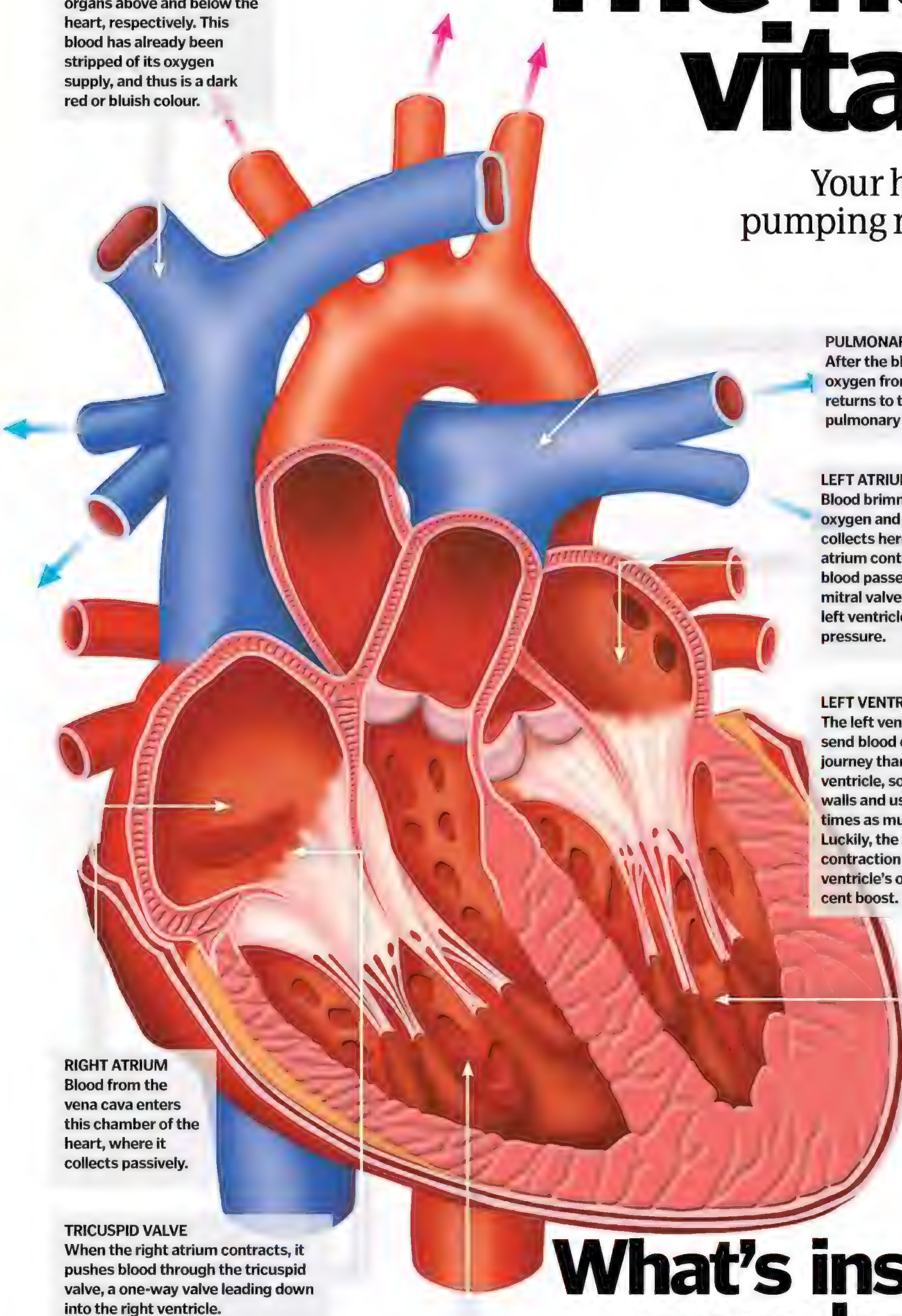
The heart is considered a double pump because the right half sends 'used' blood to your lungs. There, the blood drops off a load of carbon dioxide and picks up some fresh oxygen, which you have helpfully provided by breathing. Then the oxygenated blood returns to the left half of the heart. This 'heart-to-lungs-to-heart-again' trip is known as pulmonary circulation. The left side of the heart then pumps this oxygenated blood to every organ in your body other than your lungs. Your brain, your skin, the muscles in your thigh, your spleen – they all get blood (and therefore oxygen) by virtue of your beating heart.

Even the heart itself gets blood, via a special set of veins and arteries known as the coronary system. The myocardial muscle within the wall of the heart needs oxygen and other nutrients to keep beating. Unfortunately, the coronary arteries that do this job are very narrow, between 1.7 and 2.2 millimetres in diameter. If they become clogged with cholesterol or other fatty deposits, the heart stops working. This is bad for you.

Of course, the relatively simple concept of the double pump is fairly complex in practice. A series of valves control blood flow to the heart's four chambers, allow for the build-up of enough blood pressure to get the job done, and direct the blood to the correct

What's inside your heart

Find out how your heart pumps blood around your body



115 YEARS

LONGEST LIVING HUMAN

The oldest person was Thomas Peter Thorvald Kristian Ferdinand 'Christian' Mortensen, who died aged 115 years 252 days.

DID YOU KNOW? *The world's elderly population, individuals of 60 or over, is forecast to reach 2 billion by 2050.*

The effects of ageing

What happens to our bodies as we get older?

Many scientists are still baffled by why we age, only knowing that it makes us frail and weak, and eventually causes us to die. Visual effects of ageing are clear to see, skin wrinkles and hair greys, but there are massive changes that occur inside the body as well. Organs start to lose effectiveness, bones start to calcify and brain function decreases.

Although there have been many proposed theories for ageing, there is actually no agreed scientific reason for the process, just two commonly accepted theories. The mutation accumulation theory suggests that traits linked to ageing, which will only affect us after reproductive age, can be passed on to our offspring when we reproduce as they are neither selected for or against survival as they are neutral at that point. These kinds of mutation then build up in the population.

The other major theory is the antagonistic pleiotropy theory that states that genes which aid reproduction or growth in childhood have a cost later in life, meaning they are actively selected for when we reproduce even though they have a negative cost for the individual later on. These theories are similar, but one assumes mutations are collected without intention, and the other suggests they are selected for a reason.

Understanding ageing is very important as once we understand exactly how we age, we can then better treat problems that are brought about by ageing and then hopefully extend life expectancies across the globe.

Older doesn't necessarily mean wiser, especially after three sherries

Photosynthesis

Plants need to eat but how do they do it?

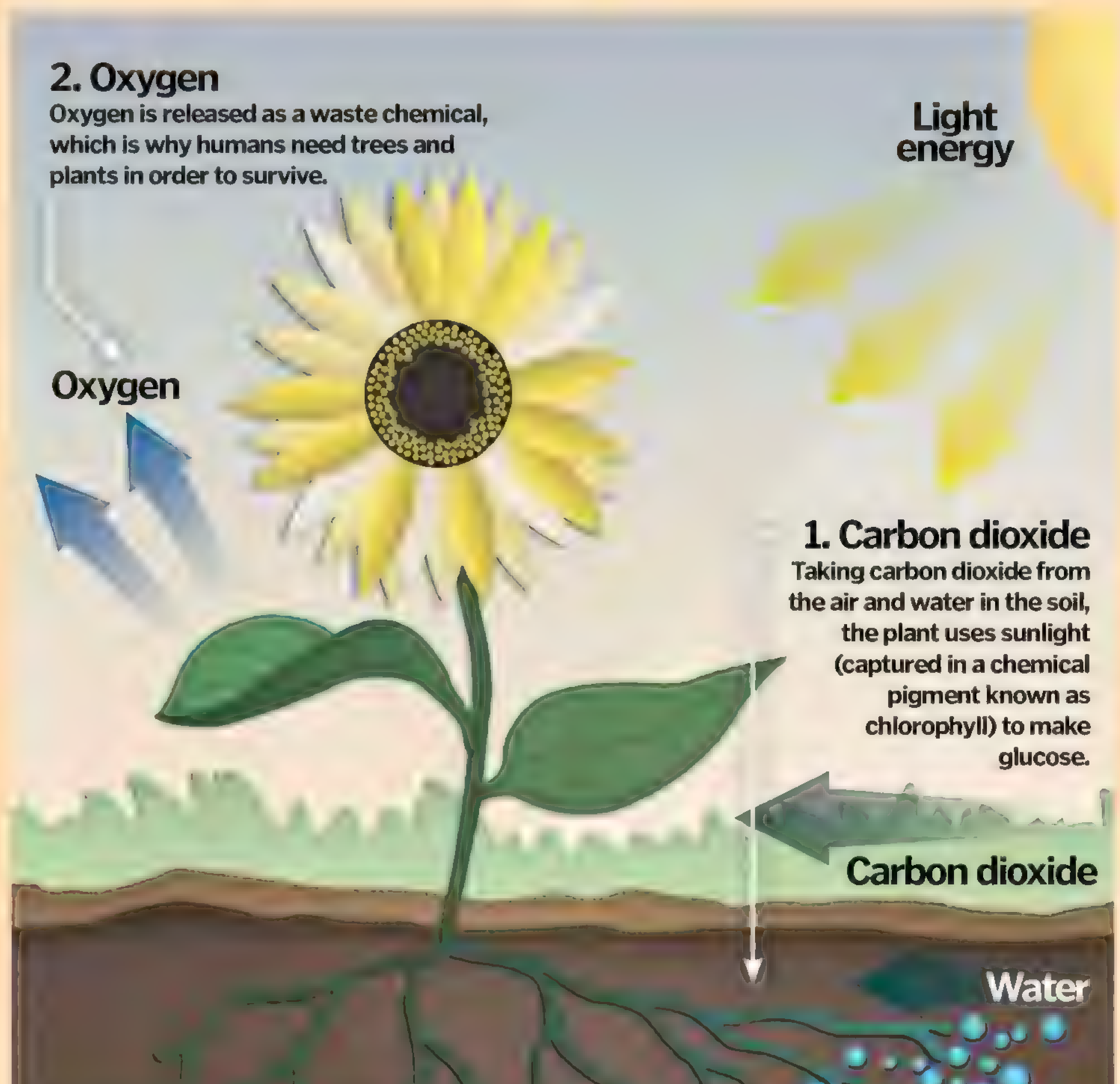
Photosynthesis is the process plants use to make food to live. Plants take carbon dioxide from the air and water (from rain) to make an organic chemical glucose – a food which plants absorb to survive. The process requires an input of energy and that is where sunlight comes in. Plants capture the energy from sunlight using a pigment called chlorophyll which converts light energy into chemical energy. Oxygen is released as a waste chemical. The formula is noted as:

Carbon dioxide + water – (sunlight) – Glucose + Oxygen, or:

$6CO_2 + 6H_2O$ – (sunlight) – $C_6H_{12}O_6 + 6O_2$

The process occurs in the leaves of the plant and each variety has evolved to make sure as much photosynthesis happens as possible, because the more a plant photosynthesises, the more food it can make and the faster and stronger it will grow – optimising its chances of survival. The leaf exhibits a waxy outer shell to restrict the loss of water as this is a crucial substance in the process.

The three ingredients a plant needs for photosynthesis to occur are carbon dioxide, water and light. The three factors which affect the rate at which a plant can produce glucose via this method is the concentration of carbon dioxide, temperature and light intensity. A plant will use glucose as a storage food substance such as starch – as in the case of potatoes or rice, or lipids in the case of seeds. It may convert the glucose into cellulose to make or repair cell walls and in other cases it forms amino acids which are used to produce proteins or chlorophyll to trap more sunlight to perpetuate the cycle.



Three ingredients are necessary for a plant to photosynthesise; carbon dioxide, water and light

50 AMAZING FACTS ABOUT SLEEP

We shed some light on some of the most complex and misunderstood sleep trivia

Just consider what happens if you don't sleep. When researchers at the University of Chicago kept rats awake continuously, the subjects developed lesions on their bodies, experienced extreme weight loss and also exhibited unusual fluctuations in body temperature. After 11-32 days without any sleep, the subjects died with no clear cause. You would likely meet a similarly gruesome end. Scientists aren't exactly sure how snoozing keeps all this at bay, or what else it does for you, however they've come up with many plausible theories.

One big benefit seems to be energy conservation. Among other things, sleep decreases your body's caloric demand and temperature, dropping your energy metabolism as much as ten per cent. The savings are even greater in some other animals. In the wild, where food is often scarce, this bio-efficiency feature could make all the difference. Slumber also seems to help restore what your body loses when you're awake. Research shows sleep is the prime time for tissue repair, protein synthesis, muscle growth and other major restorative functions. Studies demonstrate it's critical to immune system performance as well.

Finally, sleep appears to be crucial to cementing and consolidating the neural connections that form memories as well as tossing out irrelevant information from the day, making it critical to learning. Studies show that people master skills and retain knowledge better after they've slept on it. Put it all together and it's clear that sleep, with no exaggeration, is a matter of life and death.

RECORD BREAKERS
STAYING UP

264HRS

LONGEST INTENTIONAL PERIOD AWAKE

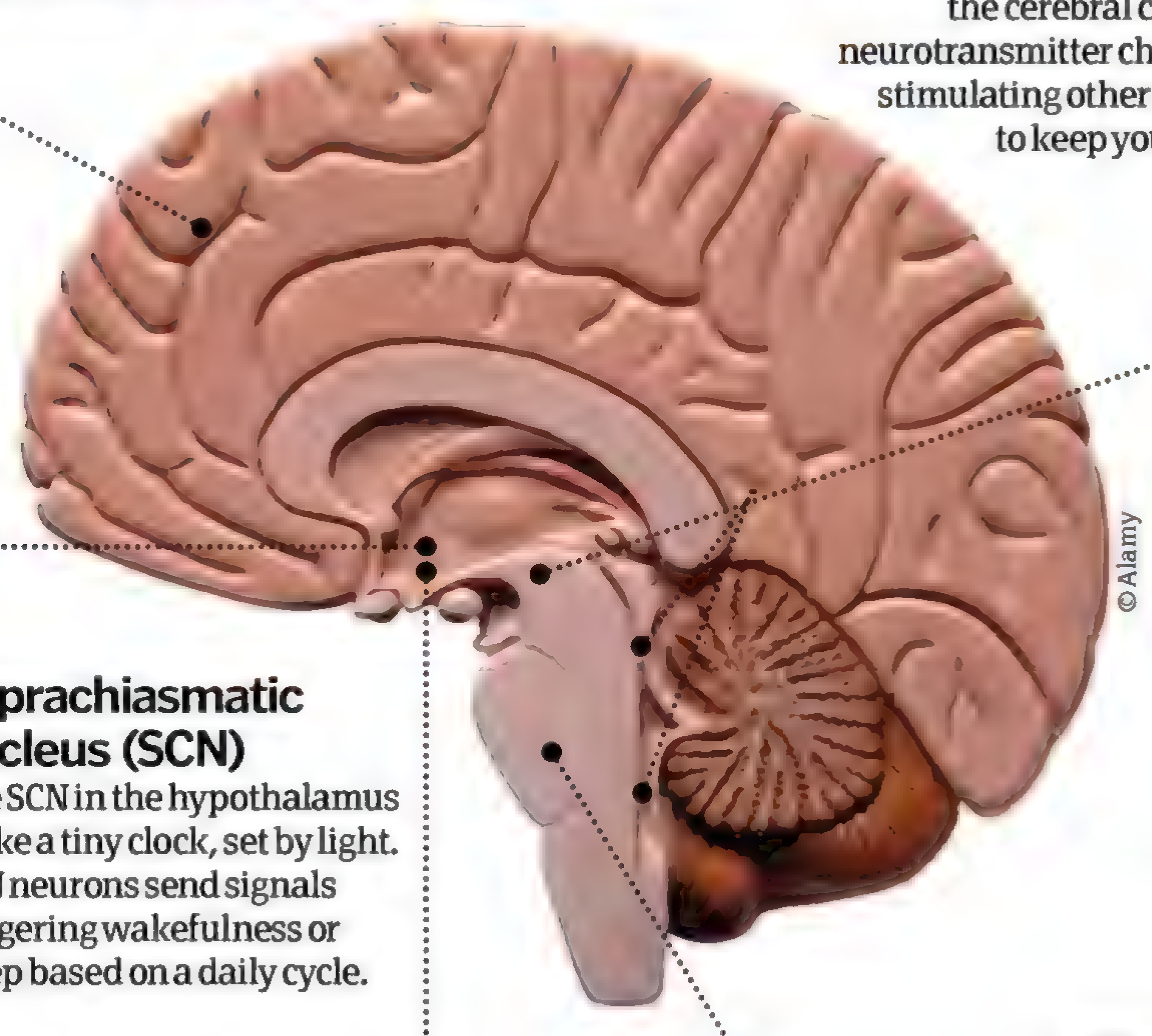
Randy Gardner stayed awake for 11 days and slept for 14 hours following this period, although Guinness World Records no longer recognises this officially on potential health grounds.

DID YOU KNOW? New babies typically deprive their parents of 400-750 hours of sleep in their first year

Which parts of the brain govern sleeping activity?

Cerebral cortex
During REM sleep, neurons in the cerebral cortex are as active or more active than during wakefulness, but in non-REM sleep, activity in the cerebral cortex greatly decreases.

Arousal centres
Areas of neurons (brain cells) within the brainstem and hypothalamus send signals to the cerebral cortex via neurotransmitter chemicals, stimulating other neurons to keep you awake.



Suprachiasmatic nucleus (SCN)
The SCN in the hypothalamus is like a tiny clock, set by light. SCN neurons send signals triggering wakefulness or sleep based on a daily cycle.

Ventrolateral preoptic nucleus (VLPO)
VLPO neurons release neurotransmitter chemicals that promote sleep by inhibiting the arousal centre neurons that keep you awake.

The pons
This triggers the thalamus to stimulate the cerebral cortex and signals other neurons to inhibit motor systems, 'paralysing' you so you don't act out your dreams.

How many dreams do we have, on average, per night?
Between 4 and 6

What makes us snore?

1. Muscles relax
When asleep, our muscles relax. This includes those lining the air passageway, such as the tongue and the soft palate, at the back of the roof of your mouth.

2. The oropharynx sags inward
In some people, part of the passageway (the oropharynx) is so constricted that the inward suction of breathing nearly closes it.

3. The mouth opens
When the passageway is so constricted, the sleeper begins to breathe through their mouth.

4. The tongue moves back
When the snorer opens their mouth, the tongue is free to slide back toward the throat, further obstructing the air passageway.

5. The uvula vibrates
The air moving through the constricted passageway vibrates the uvula and other floppy areas of the mouth/throat, producing a loud snoring noise.

What is insomnia?
Insomnia is a term for difficulties falling asleep, staying asleep or feeling refreshed after sleep. It may stem from diet, stress, disease, medication and a range of things in between. Most people experience insomnia at some point, and roughly 10-15 per cent of adults suffer from chronic insomnia.

Why do we toss and turn at night?
In some cases, the culprits are an uncomfortable bed or it being too hot or cold. You move around all night trying in vain to get comfortable. Other times, stress and anxiety prevent you from relaxing into deep sleep.

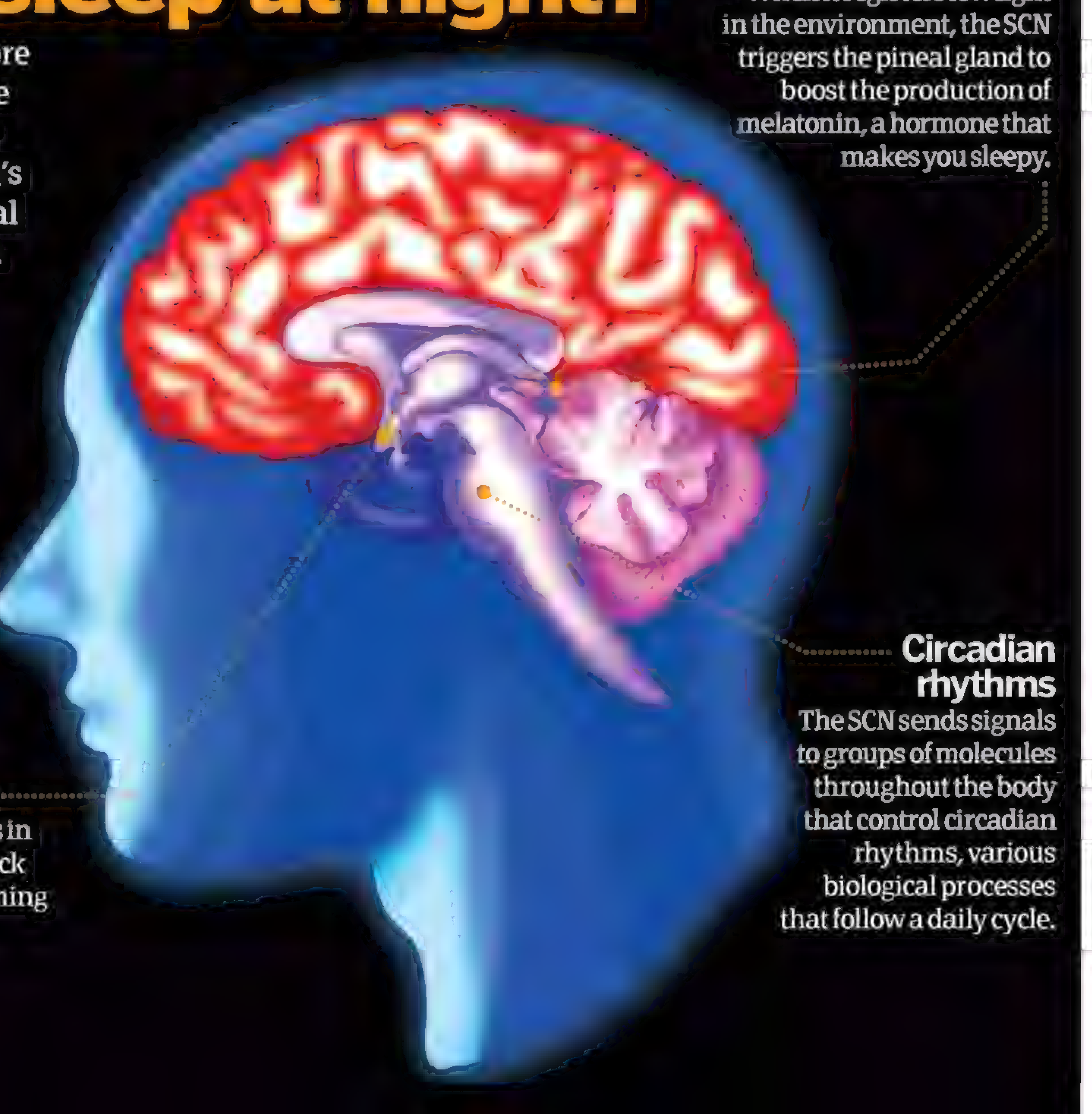
What is sleeping sickness?
Sleeping sickness is an African disease caused by the parasitic protozoa trypanosoma brucei, which is transmitted to humans via infected tsetse flies. The protozoa replicate inside the body and, without treatment, eventually invade the central nervous system. At this stage, the disease can greatly disrupt the sleep cycle.

What are bedbugs?
Bedbug is a general term for several species of tiny insect that feed on blood, usually at night. For thousands of years, the parasites have invaded our beds and attached themselves to feast. After five minutes or so, the engorged bug lets go and retreats to safety. Because of their size and tendency to hide, bedbugs are hard to detect.

Why do we sleep at night?

We sleep at night as it was safer and more productive for our ancestors to be active during the day, when they could better see potential danger. When everything's working correctly, our built-in biological clock keeps us on a day/night schedule.

Light
Your clock is naturally on a 25-hour schedule, so it needs to cue off daylight to reset itself.



Pineal gland
When it registers low light in the environment, the SCN triggers the pineal gland to boost the production of melatonin, a hormone that makes you sleepy.

Circadian rhythms
The SCN sends signals to groups of molecules throughout the body that control circadian rhythms, various biological processes that follow a daily cycle.

Suprachiasmatic nucleus (SCN)
The SCN is a cluster of around 20,000 neurons in the hypothalamus that acts as the master clock for your body, based on light information coming directly from the optic nerve.

Why do we dream?

Dreaming occurs chiefly during REM sleep, when the cerebral cortex is buzzing with activity, apparently consolidating memories. One theory is that dreams are simply the cortex's attempt to make sense of it all. Barraged with a stream of random activity, you do your best to piece it into some semblance of a story.

Others don't think it's so random. One popular theory says dreams are practice for dealing with danger. The amygdalae – the seat of the fight-or-flight response – as well as brain areas associated with running and fighting are unusually active during REM sleep. We rehearse outrunning a lion so we have some experience if it were to happen.

Another possibility is that dreaming is a way to work through problems, ideas and emotions without the constraints of logic. Interestingly, the activity of REM sleep is centred in the midline of the brain, associated with emotions. In contrast, there's little activity in areas associated with logical thinking or recall of details.

"When you deprive people of daylight, their daily cycles tend to drift, like a clock that's too slow"

Why do babies' sleep patterns differ from adults'?
Newborns spend 16-20 hours a day sleeping, rolling back to 11-12 hours by age one. In keeping with the theory that sleep is integral to learning, it makes sense for babies to need a lot of sleep when their brains are developing at a furious pace. Indeed, babies spend about twice as much time in REM sleep as adults. Similarly, sleep appears to be a key time for growth hormones to drive physical development.

Can you really learn a language while you're asleep?
Sleep learning is a beautiful notion, but there's no real evidence to back it up. In fact, listening to language recordings or subliminal weight-loss messages is likely to hinder learning by disrupting proper sleep cycles. Instead, experts recommend studying material immediately before going to sleep and letting your snoozing brain take it from there.

How does jet lag impact us?
Switching time zones makes us tired and disorientated because it throws off our internal clock. Your circadian rhythms are still running on the old cycle, which is out of step with what you're doing throughout the day. Within a few days, light levels should reset the internal clock to local time.

Can the weather affect our sleep?
Light levels definitely affect sleep, because sunlight triggers your internal clock to kick off your day. When a bright morning lights up your room, you might wake up naturally, fully refreshed. On a cloudy day, you don't get the full benefit of the internal clock kick.

How do astronauts sleep in space?
Some astronauts enjoy free-floating sleep, but most slip into sleeping bags tethered to a wall, with a pillow attached to their heads. The International Space Station includes two individual sleeping compartments, each with a window, a sleeping bag and just enough room for one person.

Why do we shut our eyes when we sleep?
One possibility is that this is the best way to block out the stream of incoming visual information that would otherwise distract the brain. Additionally, protecting your eyes from the elements at night may be important for repairing damage the eyes suffer during the day.

Is an hour's kip before midnight really worth two hours' after?

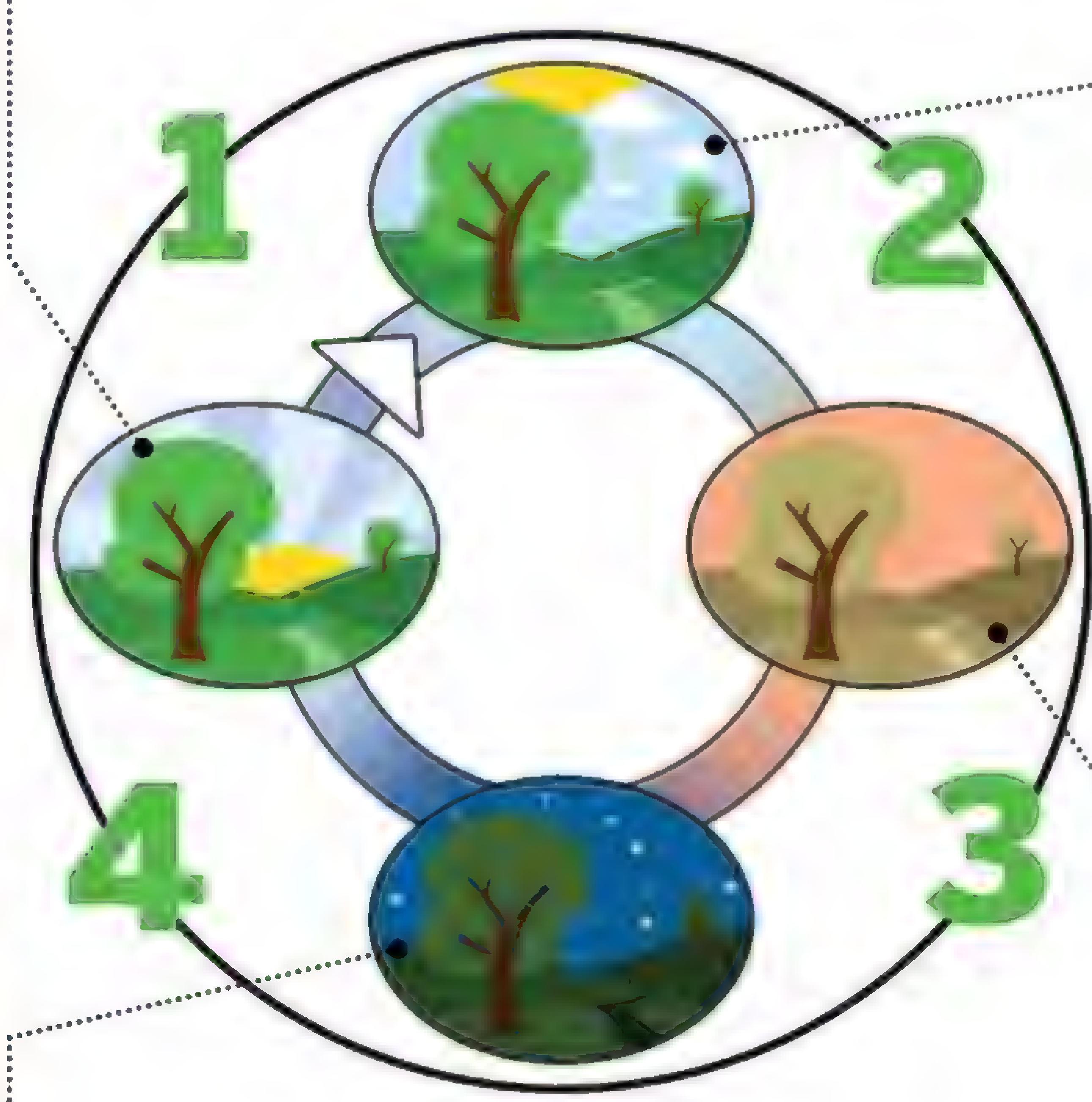
Nobody can quantify the relative value of sleep periods, but it's true that you're more likely to have non-REM sleep earlier in the night and REM later. So if you want NREM sleep, go to bed early. If you're an REM fan, then stay up late and sleep in.

How does the body clock dictate our behaviour?

Your cycle of sleeping and waking is one of many circadian rhythms in the body, controlled by a master biological clock. Circadian rhythms are biological processes that fluctuate on a daily schedule, in order to ensure your body does the things it needs to do. While circadian rhythms are self-sustaining, your biological clock regularly resets the cycles based on cues from your environment. Daylight, monitored by your master biological clock, is the most important cue. When you deprive people of daylight, their daily cycles tend to drift, like a clock that's too slow. Routine events, like alarm clocks and timing of meals, can also help to reset circadian rhythms.

1. Morning
When you get up your built-in clock slows melatonin production and triggers a sharp rise in blood pressure and testosterone secretion. By 10am, you should reach high alertness.

2. Afternoon
In the afternoon, your clock is set to have the best muscle strength, co-ordination, reaction time and cardiovascular efficiency of the day.



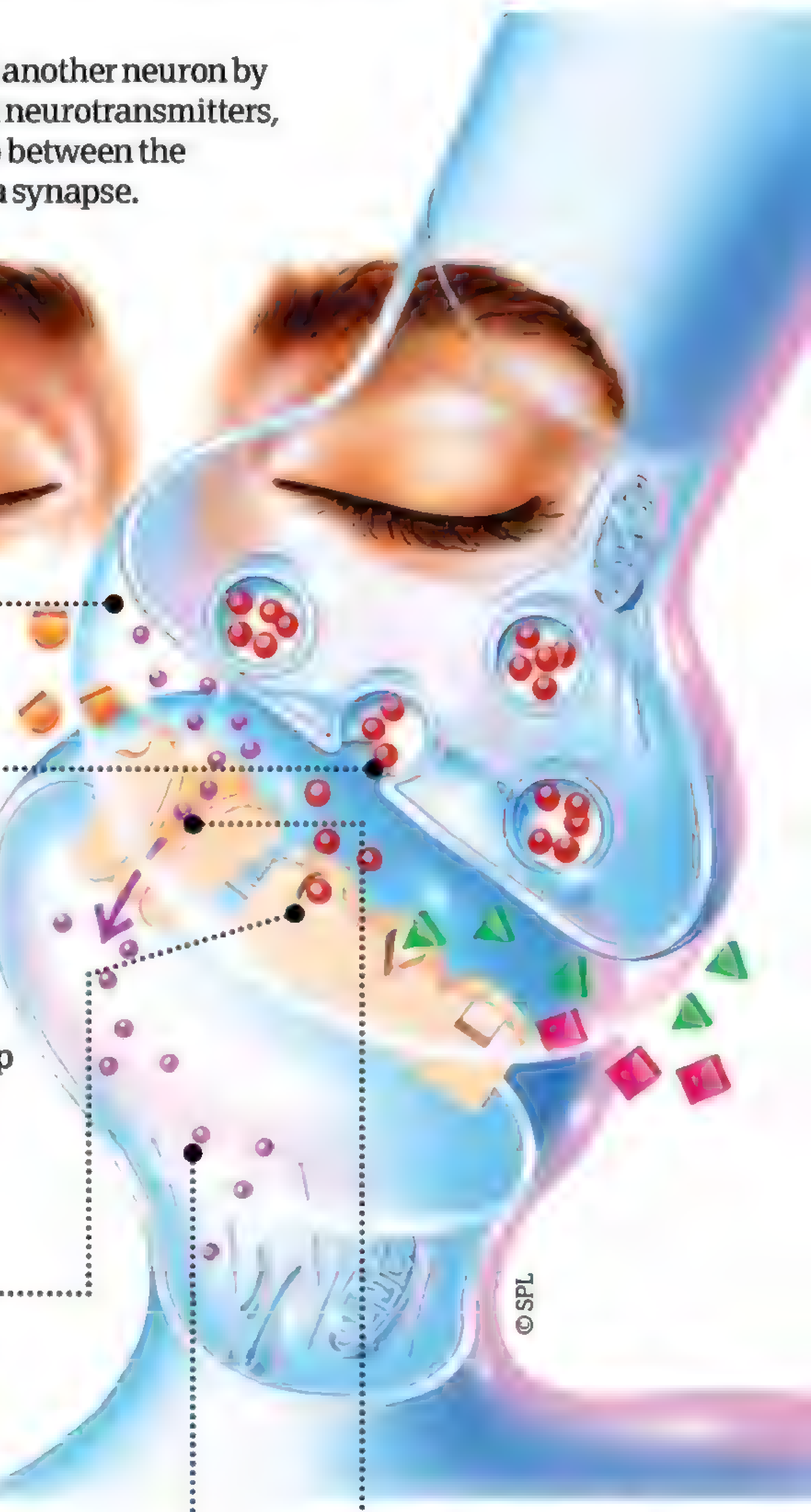
4. Night
At about 10.30pm, bowel movements are suppressed and your body is ready for sleep. You typically reach the deepest sleep around 2am.

3. Evening
In the early evening, you have the highest body temperature and blood pressure of the day. Around 9pm, melatonin secretion begins, making you sleepy.

How do sleeping pills work?

Most milder sleeping pills are antihistamines, which make you drowsy by blocking the neurotransmitter histamine. Most prescription sleeping pills, meanwhile, work by binding with gamma-aminobutyric acid (GABA) receptors in the brain, replicating a natural process that promotes sleep; this process is explained below.

1. Synapse
A neuron triggers action in another neuron by releasing chemicals called neurotransmitters, which move across the gap between the neurons; this is known as a synapse.



2. Neuron releases gamma-aminobutyric acid
One way that the brain naturally promotes sleep is by releasing a neurotransmitter called GABA. Most prescription sleep aid drugs mimic GABA to achieve the same effect.

3. GABA molecules travel to receptors
The GABA molecules bind to receptor molecules on the neuron and make the jump across the synapse.

4. Chloride channels open
The receptor neuron recognises GABA molecules binding with receptors as a signal to open channels that release chloride ions.

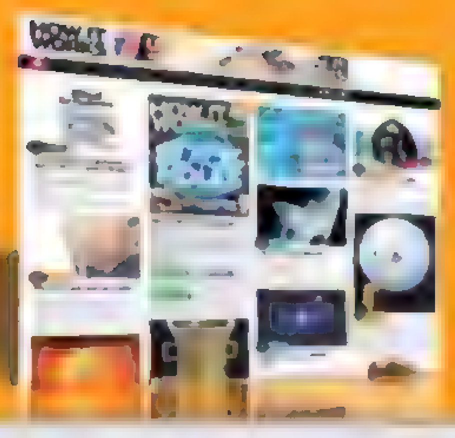
5. Chloride ions calm the cell
The chloride ions decrease the excitement level in the receptor neuron. Calming many neurons in this way leads the brain to initiate sleep.

© SPL

What are the different

0-7 mins
Stage 1
Within seconds of nodding off, you enter a brief period of light non-rapid-eye-movement (NREM) sleep, which is characterised by low-voltage brain wave activity. This stage typically lasts only seven minutes or so.

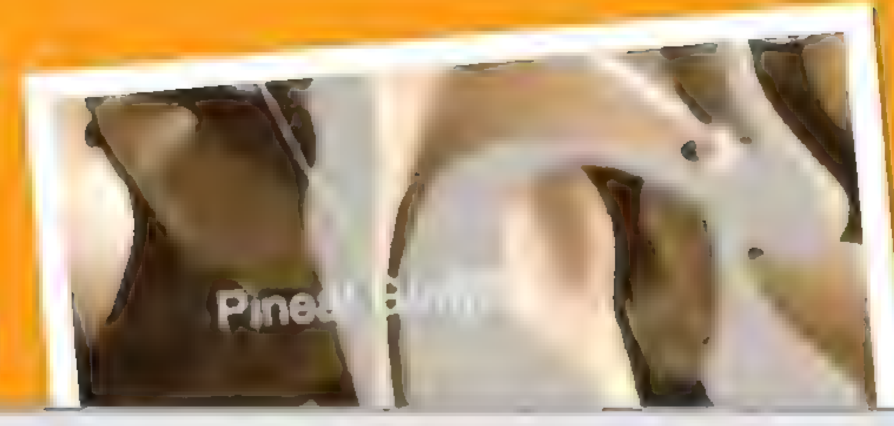
7-10 mins
Stage 2
As your brain waves gradually slow down and become more synchronised, your body temperature will drop, your breathing and heart rate become more regular, and you disengage from the outside world.



AMAZING VIDEO! SCAN THE QR CODE FOR A QUICK LINK

What happens in our brains when we sleep?

www.howitworksdaily.com



DID YOU KNOW? *Elephants sleep standing up for NREM sleep, but lie down for REM sleep*

What happens if we don't get any shut-eye?

If you went long enough without sleep, you'd suffer physical and mental decline and eventually die. Fortunately, it would be physically impossible for most of us to stay awake for that long. However, this is exactly what happens to people who are born with the rare genetic disease fatal familial insomnia (FFI). Victims of this condition gradually lose the ability to sleep and can die of apparent exhaustion within as short a period as nine months.

0-16 hours
When you start your day, a chemical called adenosine begins building up in the brain. After 16 hours of accumulation, the high adenosine level inhibits brain cells that promote alertness, which makes you drowsy.

24 hours
Levels of the hormones cortisol and thyrotropin rise after a day, boosting blood pressure. You're physically fatigued, irritable and giddy, with difficulties concentrating. Brain activity spikes radically to stimuli, making you 'twitchy'.

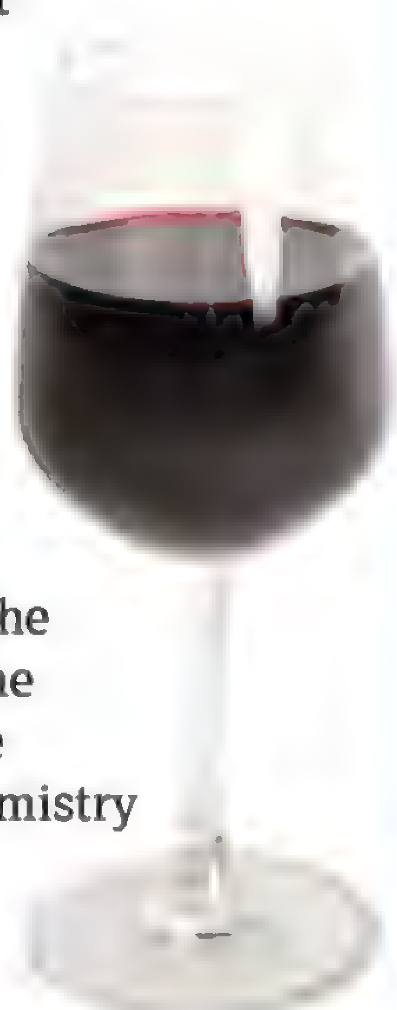
2 days
After 48 hours without any sleep, your overall body temperature will drop and your immune system weakens. You're not metabolising glucose well, making you crave carbohydrates. You'll find that concentration and mood swings worsen.

3 days
72 hours have passed without a wink of sleep and at this stage you may be experiencing visual and auditory hallucinations. Also it's likely that you'll be blacking out now and then during moments of involuntary 'microsleep'.

4+ days
When 17-year-old Randy Gardner stayed up 11 days to break the record in 1965, he thought he was a famous footballer and mistook a street sign for a person on day four. But on day 11, he was speaking coherently and even beat the sleep researcher at pinball!

How does alcohol affect sleep?

As a depressant, alcohol dampens arousal levels, making it notoriously good at helping people fall asleep quickly. However, the work of metabolising alcohol later disrupts your brain. Notably, drinking alcohol slows production of glutamine. Afterward, the body works to recover the deficit by turning up the glutamine dial. The chemistry imbalance can wake you up more often and suppress REM sleep.



How much sleep do we need a day?
7-9 hours

How do animals sleep?

Most animals follow a daily rhythm of rest and activity like us, but while all mammals and birds have REM and NREM sleep cycles, we don't all do it the same way. For example, dolphins and whales can never 'zonk out' completely as they have to go to the surface regularly to breathe. To keep from drowning, only one half of their brain sleeps at a time. Giraffes are so vulnerable while slumbering that they sleep only five minutes at a time, adding up to less than five hours a day. At the other extreme, koalas spend five hours a day eating low-energy eucalyptus leaves, resulting in a slow metabolism that forces them to sleep for the other 19 hours!

stages of sleep?

Stage 3
10-25 mins

After approximately 10-25 minutes, you enter deep NREM sleep, characterised by slow, high-amplitude brain waves. Your breathing slows down, your muscles relax, your blood pressure drops and restorative processes kick into gear.

Stage 4
25-90 mins

These days, most sleep scientists regard stage 4 simply as a continuation of stage 3. In this deepest sleep, your body repairs damaged tissues, releases growth hormones to spur development and generally restores energy levels.

Stage 5
1.5-7.5 hrs

About 90 minutes after falling asleep, you reach rapid-eye movement (REM) sleep, characterised by fast, low-amplitude brain waves and dreaming. After the REM period, the cycle repeats three to five times through a night, each time steadily longer.

Stage 6
7.5-8 hrs

Delta and theta brain waves are overtaken by higher states of consciousness as alpha waves kick in and the heart rate quickens. Opening your eyes is usually the trigger for beta waves as you return to an alert state.

Why is it so hard to recall our dreams?
A leading theory is that key brain areas and processes involved in cementing memories aren't fully active during sleep. PET scans show inactivity in the frontal lobes during REM sleep, and neurotransmitters involved in memory formation, like serotonin, are at much lower levels.

What is lucid dreaming?
Lucid dreaming is when you realise you're in a dream as it's happening. Often, the lucid dreamer can control the dream, and even back it up to take it in a different direction. Around 50 per cent of people remember at least one lucid dream, and some people have them often.

Why do we have recurring dreams?
This may be like asking why we have recurring thoughts – there could be many reasons. Some theorise recurring dreams represent a problem you haven't resolved, just like recurring daytime worries. But you might also dream about something simply because it's important to you, in the same way you revisit pleasant memories.

Why do we yawn when we're tired?
The latest idea, supported by experimental evidence, is that yawning expands and contracts the maxillary sinus to pump air into the brain, acting as a built-in cooling system that prevents overheating. When you're feeling tired, this system kicks in to help make your brain more alert.

Why do some people sleepwalk?
It's a mysterious fluke, where a sleeper enters an odd arousal state during the deep stage NREM sleep. It's more common among children than adults – 17 per cent of kids sleepwalk at some point – so it may be the result of incomplete nervous system development.

Can eating cheese before bed give us nightmares?
A 2005 study from the British Cheese Board seemed to debunk this notion. Around three-quarters of cheese-eaters in the study reported sleeping very well, which the board secretary attributed to the soothing amino acid tryptophan prevalent in cheese. Interestingly, certain cheese varieties seemed to yield particular dreaming themes. Many Stilton-eaters reported especially vivid, off-the-wall dreams, for instance.

"Typically, animals hibernate in order to survive long periods when food is scarce"

What is sleep paralysis?
Sleep paralysis is a common, terrifying condition where you wake up but can't move and, in many cases, feel an evil presence in the room. Sleep researchers attribute it to a fluke state that is partially wakefulness and partially REM sleep, which keeps your body immobile and gives you dreamlike perceptions.

What is narcolepsy?
Narcolepsy is a nervous system disorder that results in: sudden, extreme periods of drowsiness at any point throughout the day; hallucinations in the transition from sleep to wakefulness; sleep paralysis; and cataplexy, a sudden loss of muscle tone that leads the narcoleptic to collapse. The cause is often an autoimmune response, though in some cases it's unclear.

Do fish sleep?
Nearly all fish species appear to enter a sleep state, characterised by slowed body functions and reduced consciousness. Some bed down in secluded spots in coral or rocks. Fish that need to move continually to push oxygen over their gills, such as sharks, keep swimming slowly, but with reduced energy and alertness.

Is there any creature that doesn't sleep?
Sleep manifests itself so differently across varied species that it's hard to say. While researchers have identified sleep-like behaviour in animals as distantly related as fruit flies, they're far from determining it's a universal trait, and they can't definitively say that any creature gets by 100 per cent sleep-free.

What is night-eating syndrome?
Night-eating syndrome (NES) is an eating disorder, often linked with depression, that affects one to three per cent of the UK population. People with this disorder consume a large volume of food after dinner and may wake up during the night, requiring more food before they can go back to sleep.

Why do animals hibernate?
Hibernation is an adaptation that helps many animals conserve energy by remaining inactive, greatly slowing their metabolism and reducing their body temperature for days, weeks or even months at a time.

Typically, animals hibernate in order to survive long periods when food is scarce. Hibernating creatures will generally eat a lot of food before hibernation and then survive off the energy stored in their fat. The physical changes involved in hibernation are far more extreme than what happens during sleep. For some critters, hibernation doesn't even appear to be restful; indeed, some can emerge exhausted and have to catch up on sleep to recover!


© DK Images

What is sleep apnoea?
When you sleep, the muscles along your air passageway relax. This can lead the airway to narrow, causing snoring (see related question on page 25), or close completely, causing obstructive sleep apnoea (OSA). If the airway is totally blocked, your blood oxygen levels drop, triggering the brain to disrupt your sleep in order to gasp, clearing the airway. This can occur as many as 100 times per hour, keeping apnoea sufferers from getting a good night's sleep. Sufferers usually don't know it's happening until their partner reports the gasping or the resulting daytime drowsiness brings them to a sleep specialist. Treatments include weight loss, mouthpieces, breathing devices and even surgery.

What is monophasic and polyphasic sleep?
In monophasic sleep, you do all your snoozing in one session. In polyphasic sleep, you break it up into multiple sessions. Two-session, or biphasic sleep, was common before electricity extended our daylight hours. You went to bed early, got up for a while in the middle of the night, and then enjoyed a second slumber. Some swear by more extreme polyphasic sleep with many naps scattered throughout the day instead of any extended sessions.

What amount of our lives do we spend snoozing?
Around a third

How does a sleep lab work?
The chief activity is the polysomnogram. The patient arrives in the evening to sleep overnight under observation. A technician attaches electrodes to measure brain waves, muscle and heart activity, and eye movements. Belts around the patient's waist and chest monitor breathing, an oximeter gauges oxygen in the blood, sensors measure airflow through the mouth and nose, while a camera and microphone record movement and snoring. Doctors interpret all this data to diagnose sleeping problems and to prescribe the best treatment.

© Alamy

Are night terrors the same as nightmares?
Night terrors are a rare sleep disruption that mainly occur in children. During an episode, the sleeper might scream, bolt up, lash out and even run around the house. In contrast to nightmares, a night terror sufferer won't wake up or remember anything on waking.

What are some of the most common sleep disorders?
The leading sleep disorder, hypersomnia, is so common that most don't even regard it as a disorder. It's excessive daytime sleepiness, generally brought on by voluntary sleep deprivation. Insomnia, sleep apnoea and snoring are also high on the list. Restless leg syndrome is a common genetic condition characterised by crawling, aching or searing feelings in the legs that only fade when the sufferer moves. When episodes occur at night, they can greatly decrease the quality of sleep and there's no known cure. Bruxism is the clinical name for teeth clenching or grinding. Lifestyle changes are the most common cure for bruxism, and mouth guards are often used to prevent tooth damage.

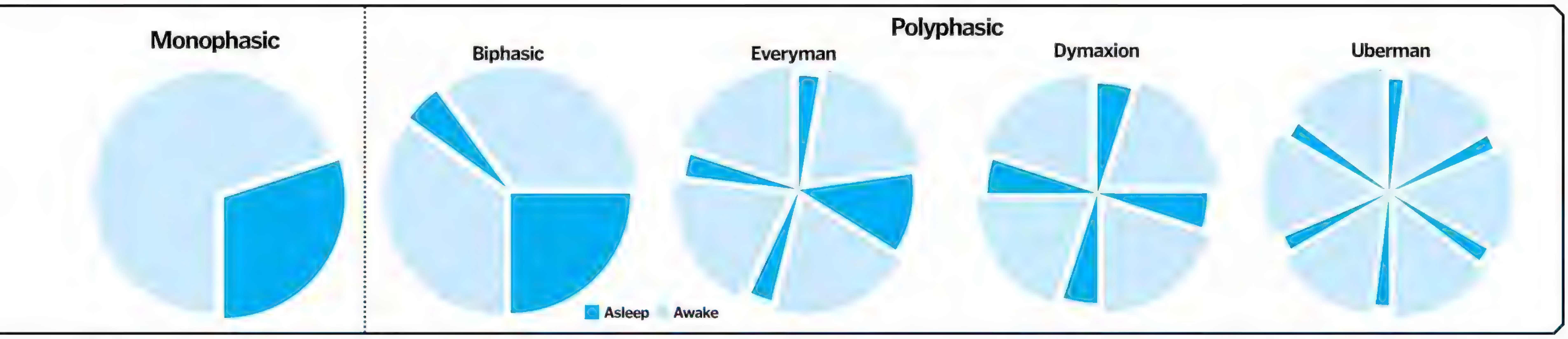
STRANGE BUT TRUE

SLEEPING BEAUTY ISN'T JUST A STORY

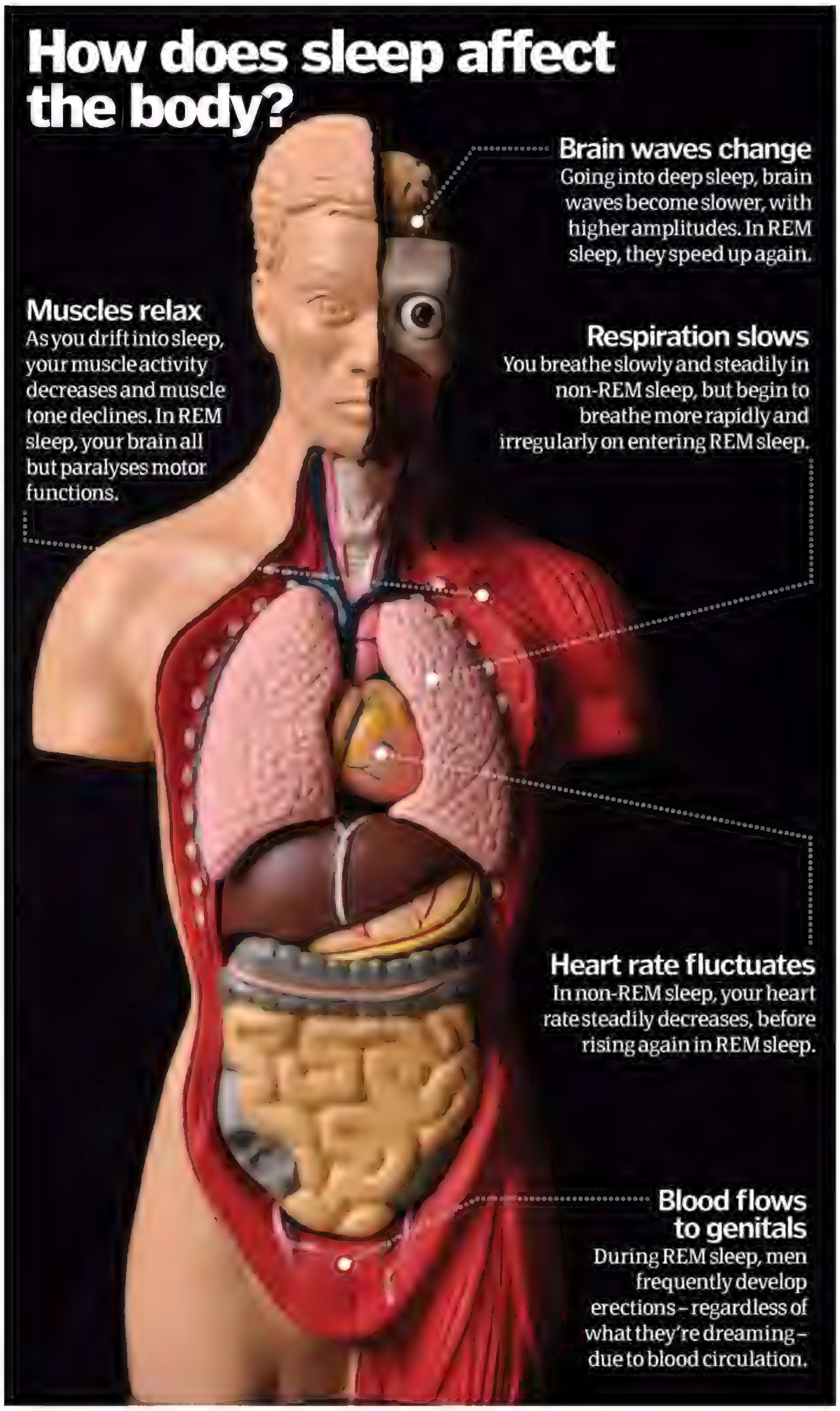
SLEEPING BEAUTY SYNDROME

Kleine-Levin, or Sleeping Beauty, Syndrome is a rare sleep disorder where an otherwise healthy individual can periodically fall asleep for days and even weeks on end. It only affects around 1,000 people worldwide.

DID YOU KNOW? *Sleep deprivation has been attributed to human errors that caused many disasters, such as Chernobyl*



How does sleep affect the body?



Brain waves change
Going into deep sleep, brain waves become slower, with higher amplitudes. In REM sleep, they speed up again.

Muscles relax
As you drift into sleep, your muscle activity decreases and muscle tone declines. In REM sleep, your brain all but paralyses motor functions.

Respiration slows
You breathe slowly and steadily in non-REM sleep, but begin to breathe more rapidly and irregularly on entering REM sleep.

Heart rate fluctuates
In non-REM sleep, your heart rate steadily decreases, before rising again in REM sleep.

Blood flows to genitals
During REM sleep, men frequently develop erections – regardless of what they're dreaming – due to blood circulation.

What is the optimum temperature for sleeping?

15-20°C (60-68°F)

What ways are there to help get to sleep?

First, reinforce the circadian rhythms of your internal clock by maintaining a consistent bedtime and wake-up routine and exposing yourself to plenty of sunlight in the morning. Next, keep your body clear of stimulants and excitement for at least three hours before bedtime. This includes chemical stimulants, like caffeine, as well as high-energy processes like digestion and exercise. Exercising earlier in the day is a great sleep aid, but too close to bedtime and the resulting flood of the stress hormone cortisol will probably keep you up.

Certain activities, like working or discussing stressful topics, can also trigger cortisol secretion. Stick to reading and other relaxing activities. Better yet, take a hot bath. Warming up and then cooling down will naturally induce drowsiness.

Finally, be sure to make your bedroom a true sleep haven. Invest in a comfortable mattress, minimise light, block out sounds with the white noise from a fan, and keep the temperature on the cool side.

Which are the sleepiest nations?

1 France The French lead the developed world with an average of 8.83 hours daily.

2 USA Americans come in second in the slumber stakes, at 8.63 hours a day.

3 Spain Next is Spain, with 8.56 hours of sleep per day. That's a lot of siesta time!

4 Australia Australians are close behind the Spanish, with an 8.53-hour daily average.

5 Canada Canadians are number five in the roundup, sleeping an average 8.48 hours a day.

Source: OECD

Does counting sheep actually work to send us to sleep?

When scientists at Oxford put this technique to the test, it came up short. In fact, study participants took longer to get to sleep on nights they counted sheep than on nights they pictured relaxing imagery.

Can we have too much sleep?

While the connection isn't clear, there are correlations between excessive sleep and medical problems, including fatal ones. A study showed people who slept more than nine hours daily had a 50 per cent greater risk of diabetes than seven-hour sleepers. Other studies suggest increased risk of obesity, heart disease, back pain and headaches.

Why do so many people wake up grumpy from a deep sleep?

The sleep cycle is a steady, gradual transition between states. When it proceeds naturally, you move gracefully out of the deepest sleep level and through REM sleep before waking up. When you go directly from deep sleep to wakefulness, you can't ease into consciousness. You're highly disoriented, making you grumpy.

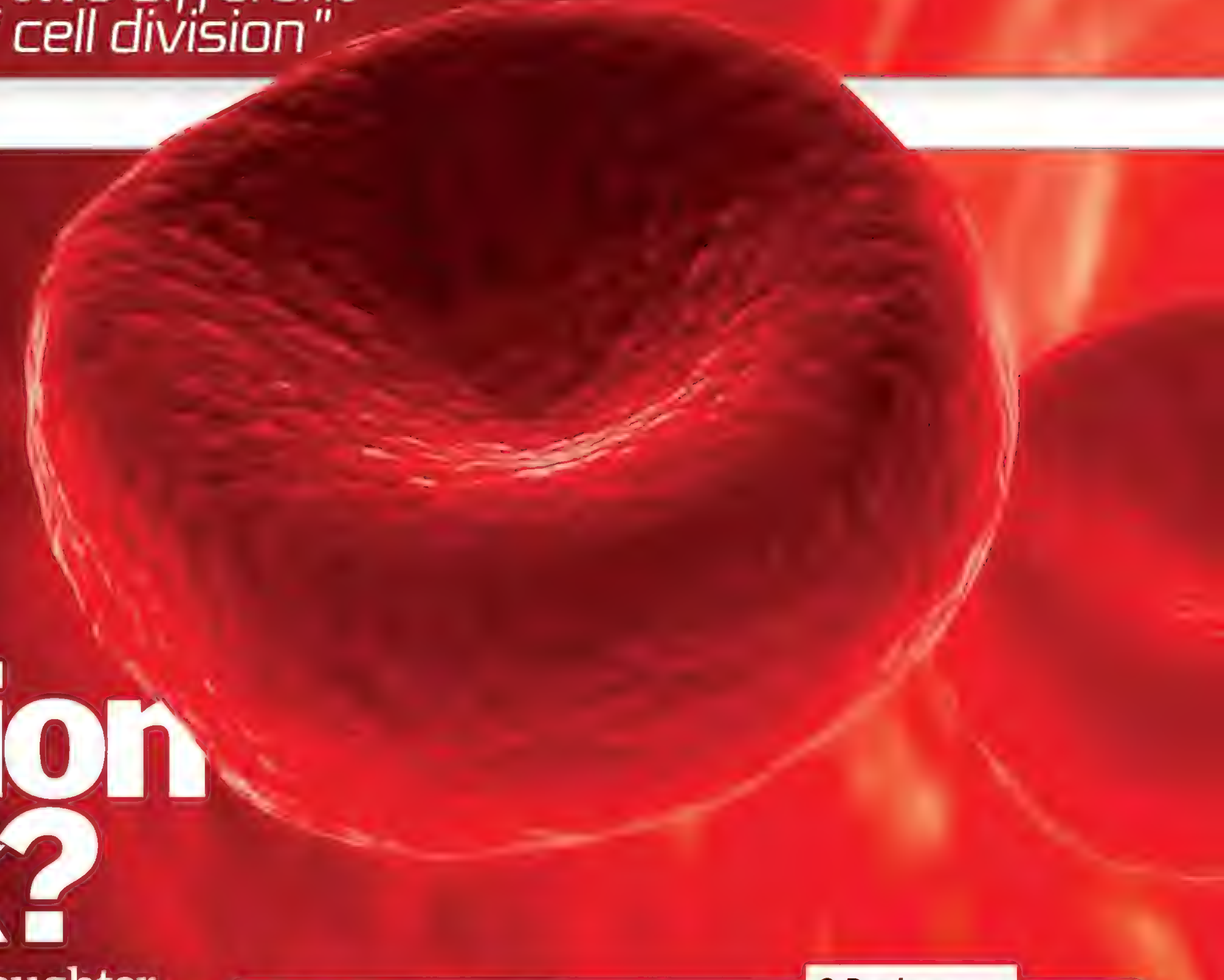
Why do we often jolt awake when close to sleep?

The jolt, known as the hypnic jerk, is a muscle spasm. The popular theory goes that your brain sometimes misinterprets the muscle relaxation of going to sleep as a falling sensation. To save you from a tumble, your brain triggers an abrupt 'catch yourself' reflex.

How long should it take to drop off?

The ideal is 10-15 minutes. If it takes less than five minutes, you're probably sleep-deprived. If you're lying in bed for 20-plus minutes, it's best to get up and do something relaxing until you feel tired.

> "As eukaryotes, our cells undergo two different types of cell division"



How does cell division work?

Like parent, like daughter – every multi-celled organism started out as a single cell

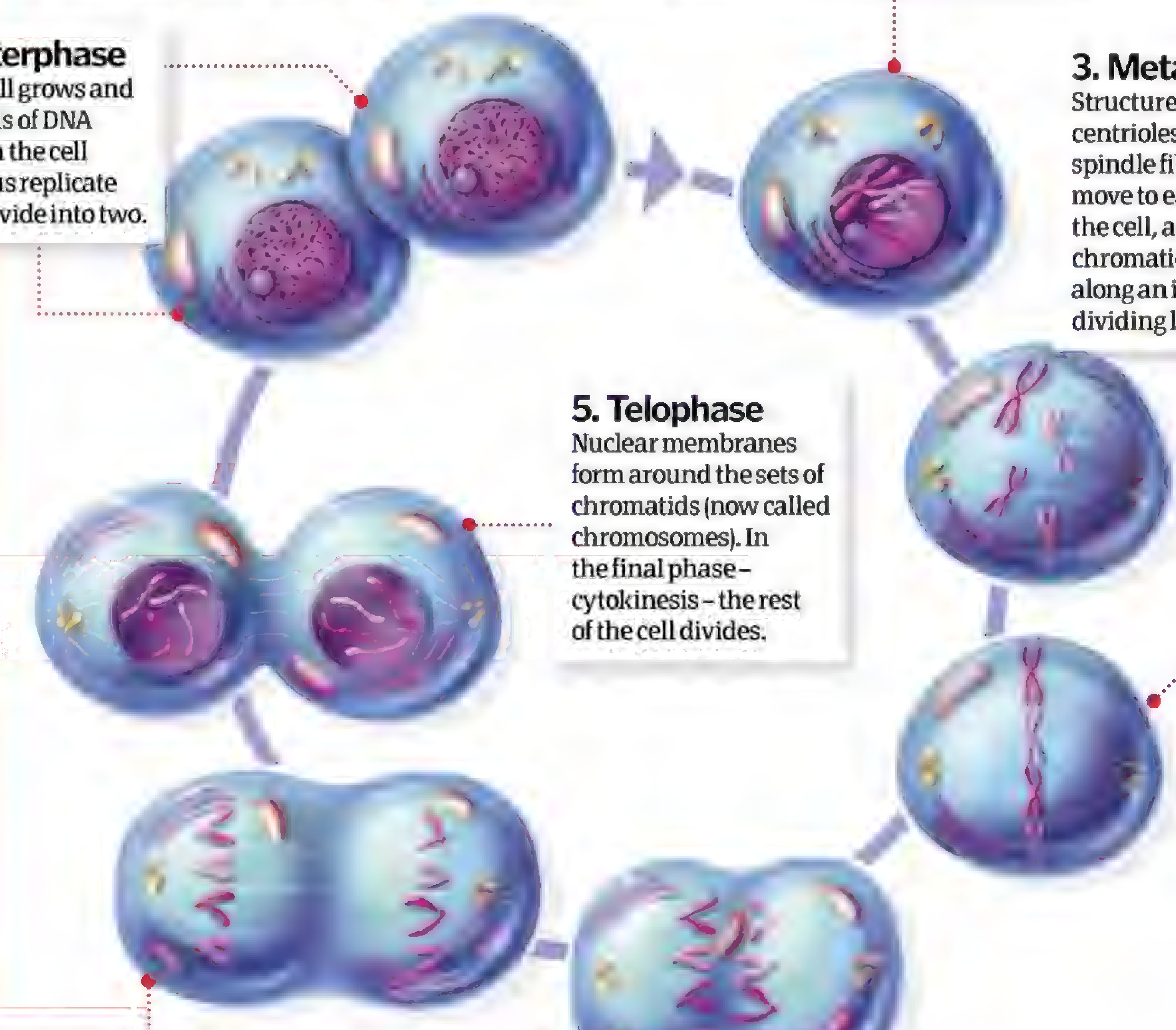
Simple-celled organisms such as bacteria are known as prokaryotes because they lack the nucleus in which genetic material is stored in most other organisms. Instead of keeping their genetic information organised in ordered chromosome sets, prokaryotic cells store their DNA in an irregularly-shaped nucleoid structure which is not bound by a membrane.

Human cells – and all other multi-celled organism in existence – are are eukaryotic. As eukaryotes, our cells undergo two different types of cell division depending on the type of cell: meiosis and mitosis. Both are complex, multi-step processes that happen very quickly. In order to sexually reproduce, our bodies create special sex cells called gametes (in animals we call these sperm in males, and eggs in females). Gametes are haploid cells because they contain 23 chromosomes, which are considered a single set. During reproduction, they merge to form a cell containing 46 chromosomes, called a diploid. But first, meiosis splits the original diploid cells, with the chromosomes duplicating, shuffling and reforming into four unique haploid cells.

In contrast, mitosis produces two identical haploid cells. It's a different process from the prokaryotic asexual reproduction, but in humans and other multi-celled organisms it's a sort of maintenance programme. Your body is undergoing mitosis constantly as all sorts of cells die and are replaced. Each human has between 50 and 75 trillion different cells and about 200 different types of cell.

Mitosis

Mitosis is the process by which our bodies replace cells. It starts with a diploid cell containing 46 chromosomes…



1. Interphase
The cell grows and strands of DNA within the cell nucleus replicate and divide into two.

2. Prophase
The 92 chromosomes consolidate into visible X-shaped structures called chromatids. The cell's nucleus begins to break down.

3. Metaphase
Structures called centrioles form spindle fibres that move to each side of the cell, and the chromatids line up along an imaginary dividing line.

4. Anaphase
The spindle fibres pull the chromatids towards opposite sides as the cell begins to split.

5. Telophase
Nuclear membranes form around the sets of chromatids (now called chromosomes). In the final phase – cytokinesis – the rest of the cell divides.

KEY DATES
CELL HISTORY

1665
Natural philosopher Robert Hooke first finds cells while studying cork under a microscope, naming them after monks' cells.

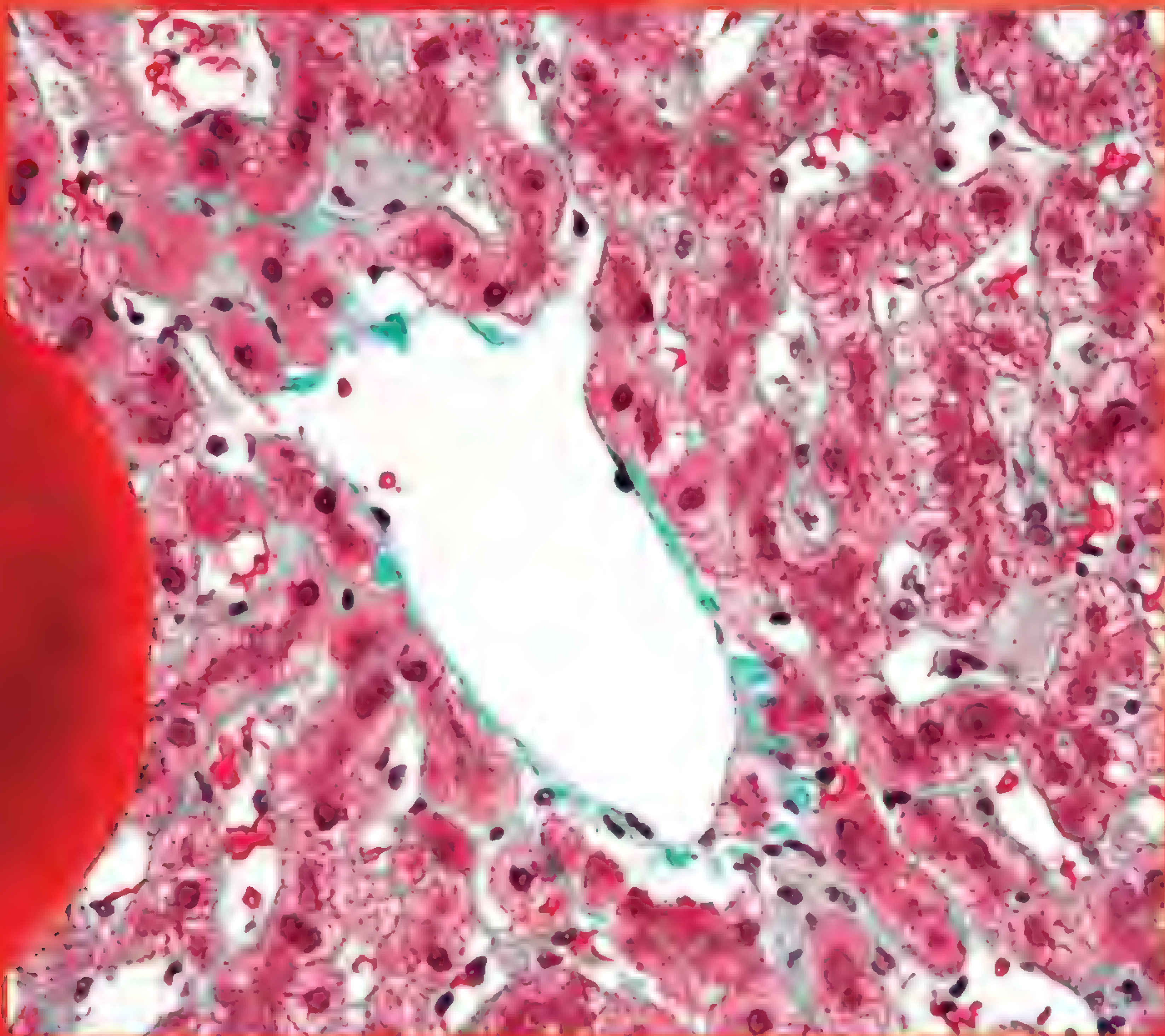
1835
Physiologist Jan Purkinje observes cells in both animal and plant tissue; he refers to them as 'granules'.

1839
The theory that cells are the building blocks of life is proposed by physiologist Theodor Schwann (left) and botanist Matthias Schleiden.

1855
Doctor Robert Remak (left) proposes all cells come from pre-existing ones that divide.

1869
Nucleic acid, which includes DNA and RNA, is first isolated by doctor Friedrich Miescher.

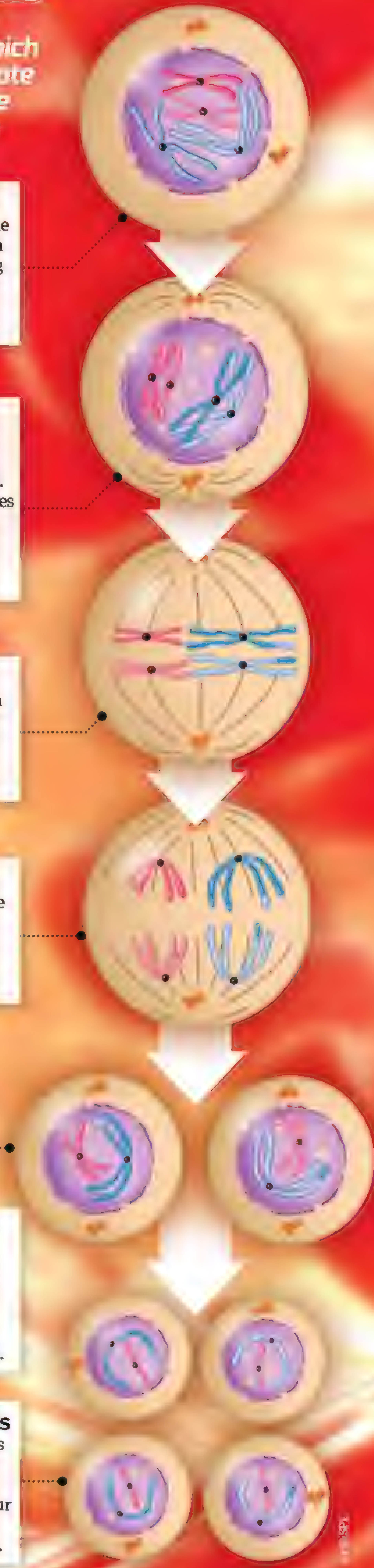
DID YOU KNOW? *Mitosis in female sex cells ends after the first round of division unless the cell is fertilised by a male sex cell*



A normal cell in humans can only divide 52 times before dying, known as the Hayflick limit

Meiosis

Meiosis is the process by which our bodies create sex cells so we can reproduce



1. Parent cell
Meiosis starts the same way as mitosis – with a diploid cell containing 46 chromosomes. The DNA strands replicate and divide.

2. Prophase
The chromosomes match up with their corresponding strand. Enzymes remove pieces of DNA from each and genes swap between the chromosomes before re-pairing.

3. Metaphase
At this point, unlike in mitosis, chromosome pairs line up on either side of an imaginary line in the cell.

4. Anaphase
Next, the chromosome pairs separate, with half moving to one side and half moving to the other.

5. Telophase
Nuclei start to form around each chromosome as the cell divides into two daughter cells, each with 46 chromosomes.

6. Daughter cells
The two daughter cells go through the entire process again, ultimately forming four daughter cells, each with 23 chromosomes.

Tumours

Tumours can be malignant (cancerous) or non-malignant, and at their most basic are the result of abnormal cell growth. The nucleus of every cell contains material that tells the cell when it's time to grow and divide (mitosis). There's a strict balance so that the new healthy cells are always replacing old, dying or damaged cells. Sometimes, however, cells get the message to grow and divide more often than they're supposed to, throwing off the equilibrium. Typically this comes from a genetic mutation – that is, there's a problem with the programming. These genetic mutations can be caused by anything from environmental factors to viruses. In cancerous tumours, the cells don't die like normal cells – instead, the mutation allows them to replicate indefinitely.

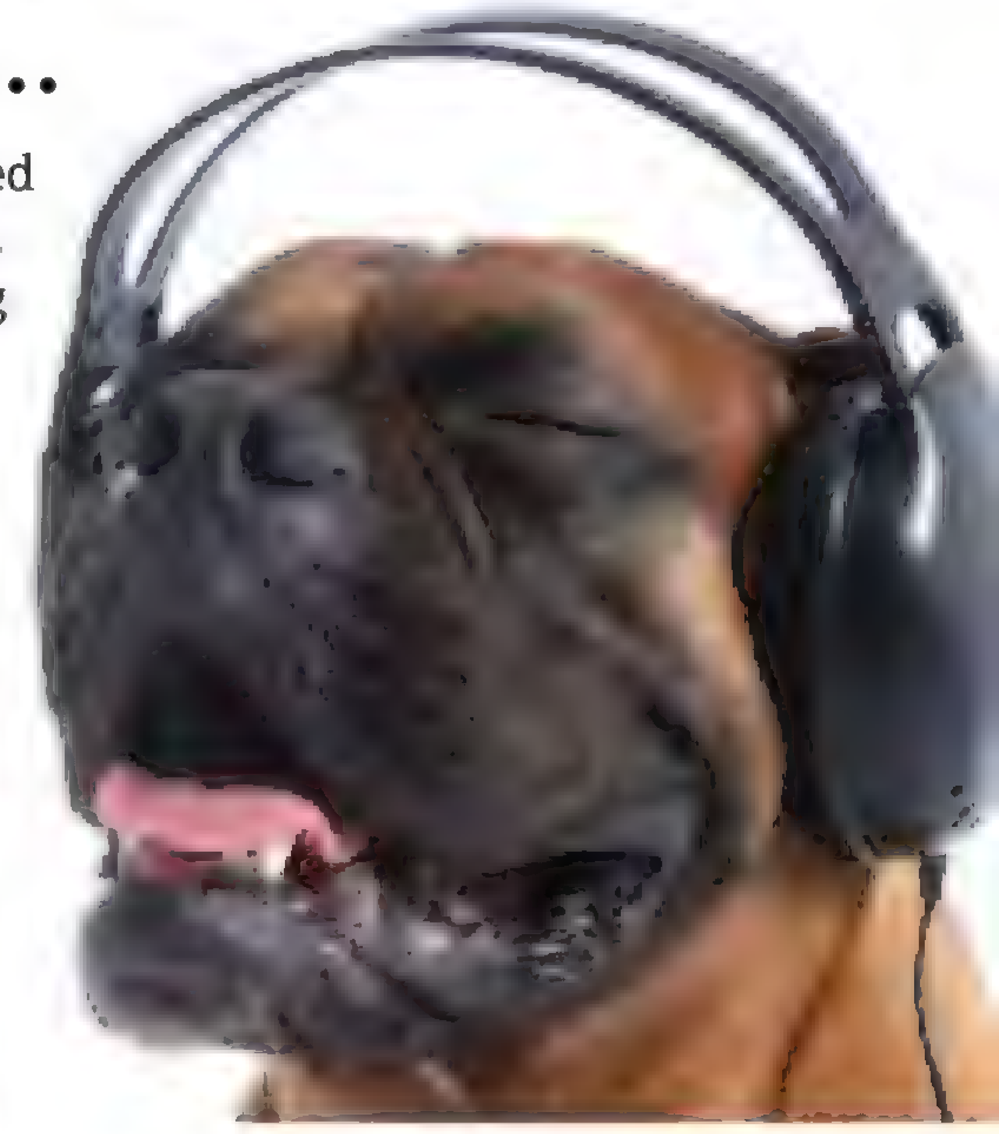
Why can dogs hear better than humans?

Identifying why Fido can hear better than you…

A full check-up made this dog paws for thought…

The biology of a dog's ear compared to a human's ear is quite different. Dogs also have a far wider hearing range than humans, allowing them to detect sounds far above a human's auditory limit.

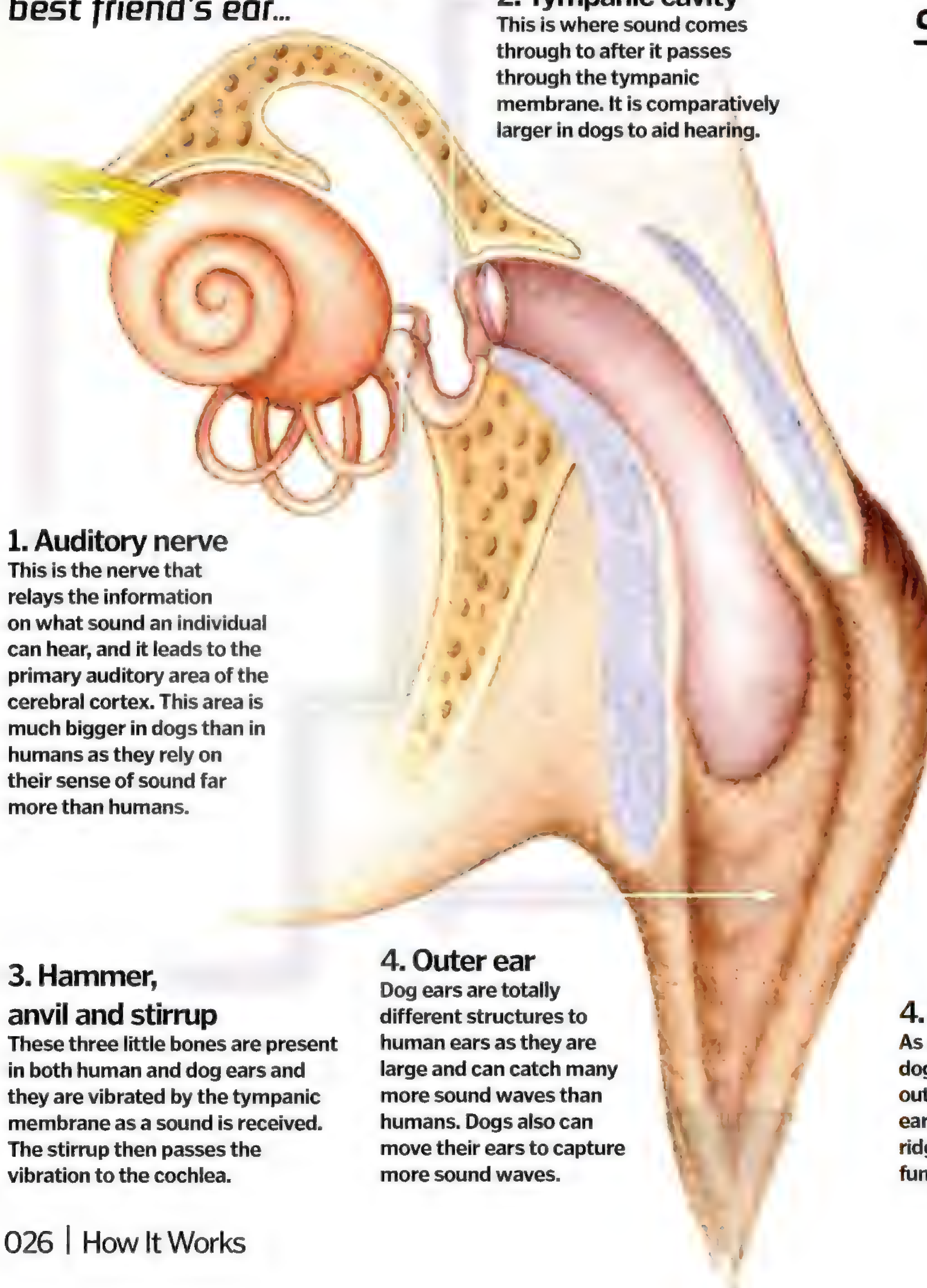
One of the major differences in biology is the size and shape of the outer ear. This is the part of the sensory organ responsible for catching sound. Dogs have far bigger outer ears, which are also mobile, and dogs use 18 muscles located in and around the outer ear to rotate, raise or lower the ear to aid hearing. They can identify a sound and its location much quicker than humans, and can hear sounds four times as far away as humans.



"One of the major differences in biology is the size and shape of the outer ear"

Inside a dog's ear

The anatomy of man's best friend's ear…



© DK Images

2. Tympanic cavity
This is where sound comes through to after it passes through the tympanic membrane. It is comparatively larger in dogs to aid hearing.

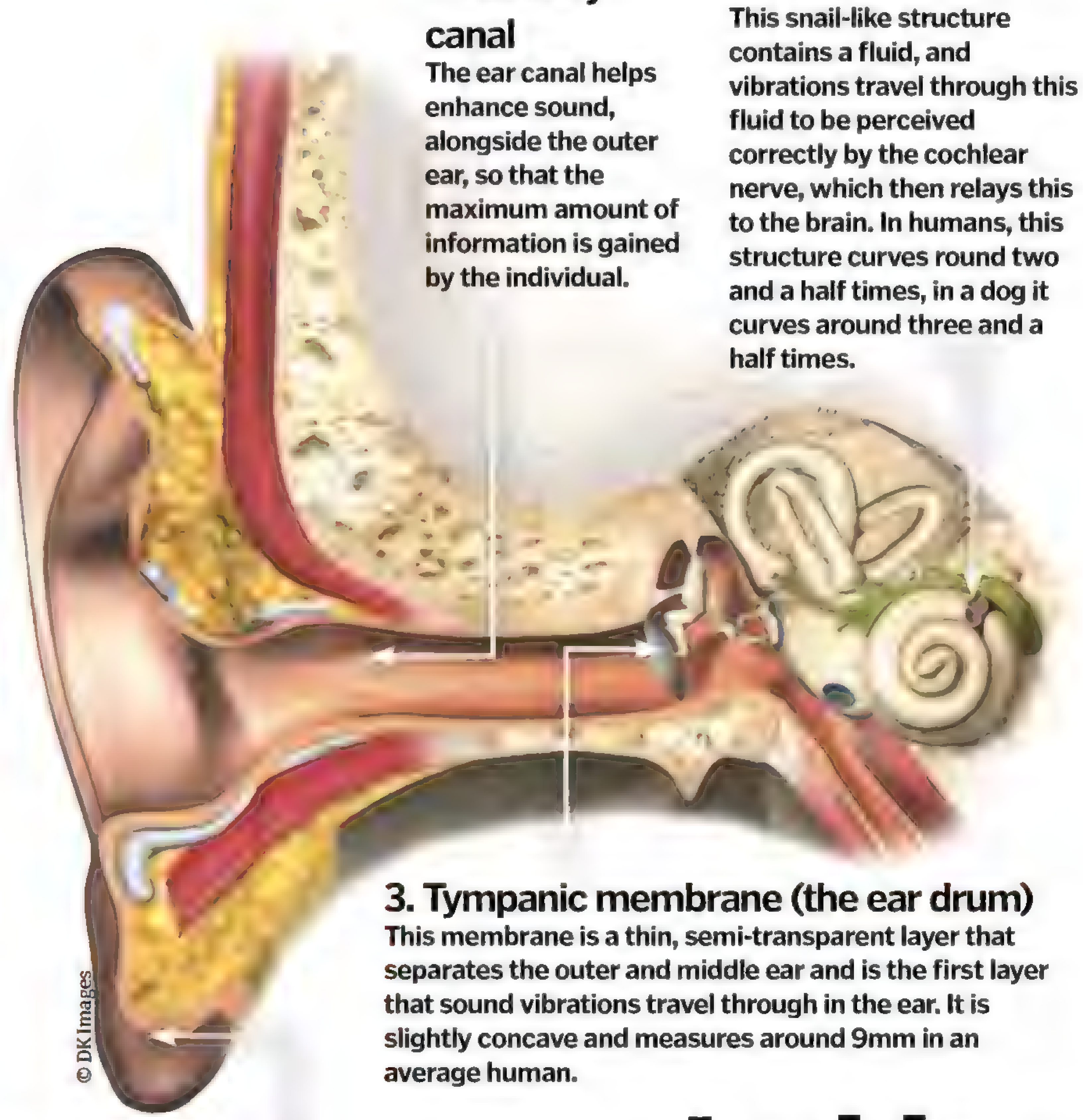
1. Auditory nerve
This is the nerve that relays the information on what sound an individual can hear, and it leads to the primary auditory area of the cerebral cortex. This area is much bigger in dogs than in humans as they rely on their sense of sound far more than humans.

3. Hammer, anvil and stirrup
These three little bones are present in both human and dog ears and they are vibrated by the tympanic membrane as a sound is received. The stirrup then passes the vibration to the cochlea.

4. Outer ear
Dog ears are totally different structures to human ears as they are large and can catch many more sound waves than humans. Dogs also can move their ears to capture more sound waves.

Inside a human ear

How do we hear and decipher sounds?



© DK Images

1. Auditory canal
The ear canal helps enhance sound, alongside the outer ear, so that the maximum amount of information is gained by the individual.

2. Cochlea
This snail-like structure contains a fluid, and vibrations travel through this fluid to be perceived correctly by the cochlear nerve, which then relays this to the brain. In humans, this structure curves round two and a half times, in a dog it curves around three and a half times.

3. Tympanic membrane (the ear drum)
This membrane is a thin, semi-transparent layer that separates the outer and middle ear and is the first layer that sound vibrations travel through in the ear. It is slightly concave and measures around 9mm in an average human.

4. Auricle (outer ear)
As opposed to the large outer ear seen on dogs, humans have a comparatively small outer ear made up of cartilage. Human outer ears are also immobile with hollows and ridges we see forming a type of irregular funnel, leading into the ear canal.

5 TOP FACTS
COLD TRUTHS

Feeling ill
1 It's not the cold that makes you feel under the weather, it's actually your immune system fighting back, triggering excess mucus to try and flush out the virus.

Who suffers
2 People who spend a lot of time with children will suffer from more colds. So mothers, childminders and school teachers are more likely to pick them up.

Yellow mucus
3 Mucus turns from clear and runny, to thick and yellow or green. This is caused by the infection-fighting white blood cells that increase in number.

Blocked nose
4 A blocked nose isn't due to mucus, but because of inflamed blood vessels inside the nasal lining. They swell up as white blood cells take over.

48 hours
5 The time it takes for a cold to materialise is around two days. After this time, symptoms such as coughing and a runny nose will appear.

DID YOU KNOW? XXXXXXXXXXXX

Why is there no cure for the common cold?

A general term for over 200 different viruses, why is the common cold so 'incurable'?

The common cold is a viral infection that attacks the upper respiratory tract, including the nasal cavity, the pharynx (back of the mouth) and the larynx (voice box). Every child can get up to 12 colds a year, and in adulthood we continue to get them on a regular basis. The symptoms of a cold are sneezing, a runny nose, sore throat and nasal congestion. Young children can also run a high temperature. In the first three days, the cold is highly contagious and is spread to anyone who inhales or touches anything contaminated by the virus. A cold lasts about a week, although a cough can persist for several days afterwards.

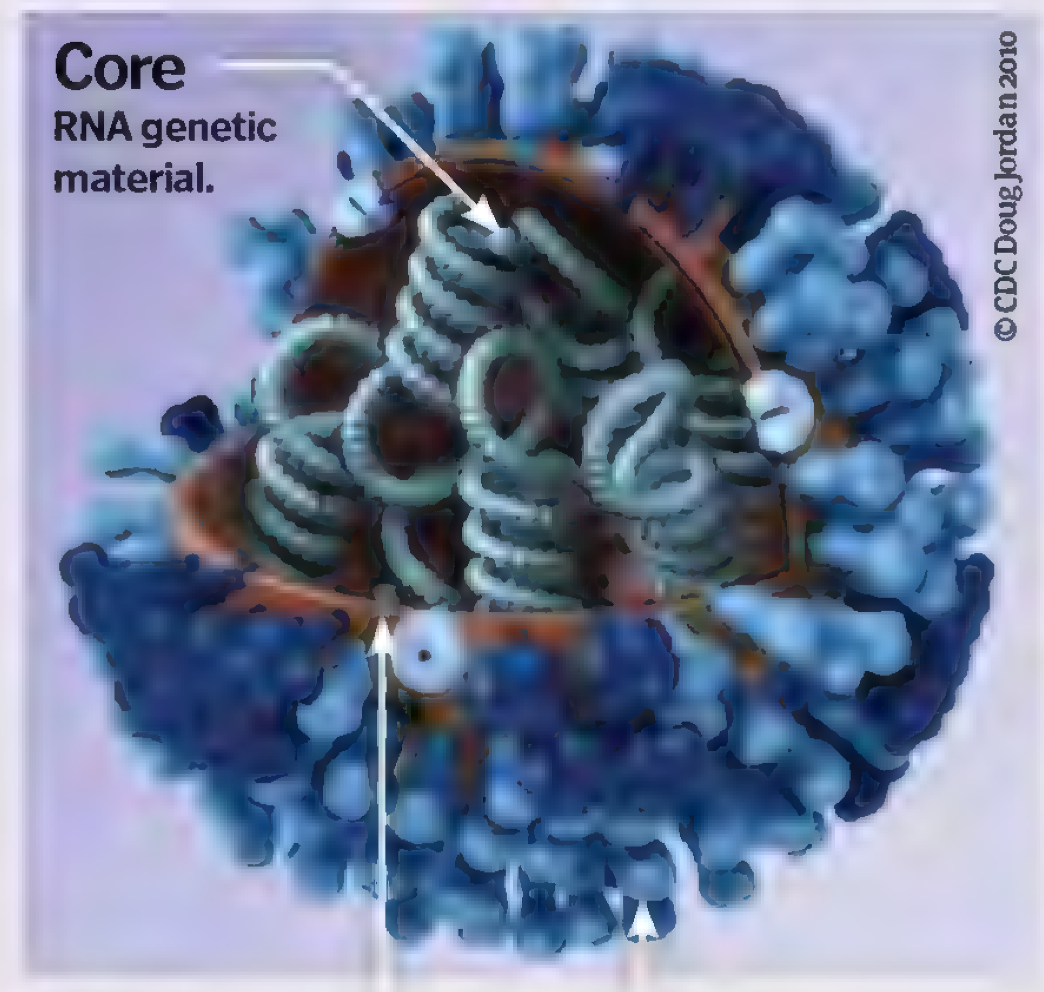
Rhinoviruses, coronaviruses, coxsackieviruses and adenoviruses are just some of the many different types of cold viruses. These viruses stick to the cells of the adenoids at the back of your throat. They quickly reproduce and rupture from the cells to spread to cells in the rest of the upper respiratory tract.

While we can treat the symptoms of a cold, we cannot find a single cure as there are so many types of virus and they mutate rapidly. Therefore, in the time it takes to develop a vaccine, it is no longer useful.


A heavy cold (sometimes referred to as 'man flu') can be debilitating

What is a virus?

Unlike bacteria, which have a cellular structure, viruses are much smaller and must replicate within other cells – for example, within the cells that line the inside of the nose.



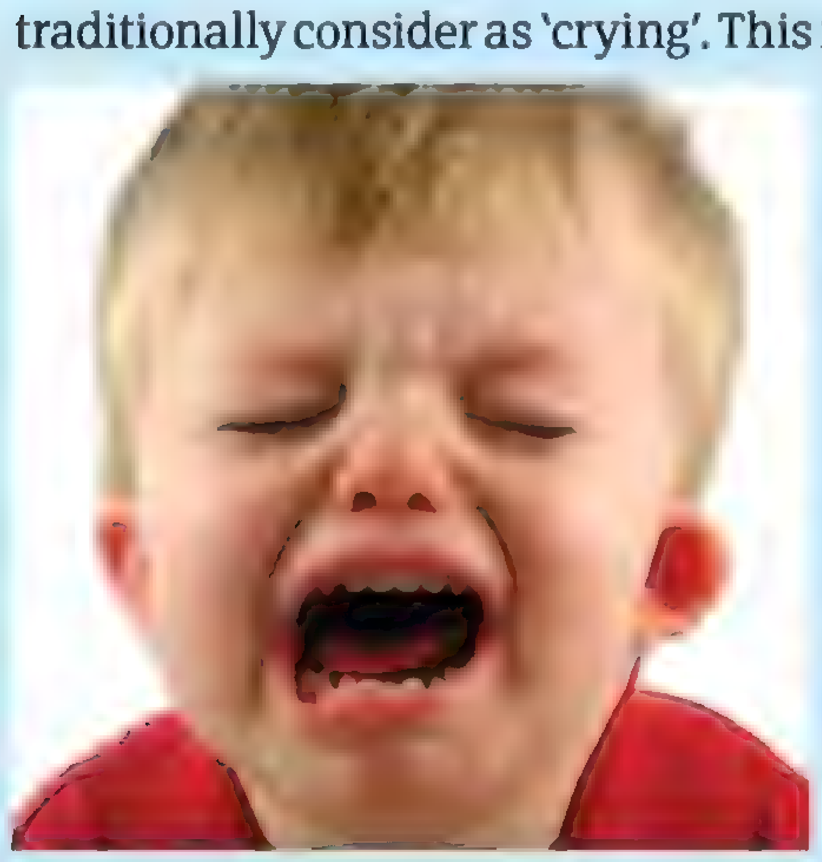
Capsid
This protein coat encloses the virus's genetic information within the host cell.

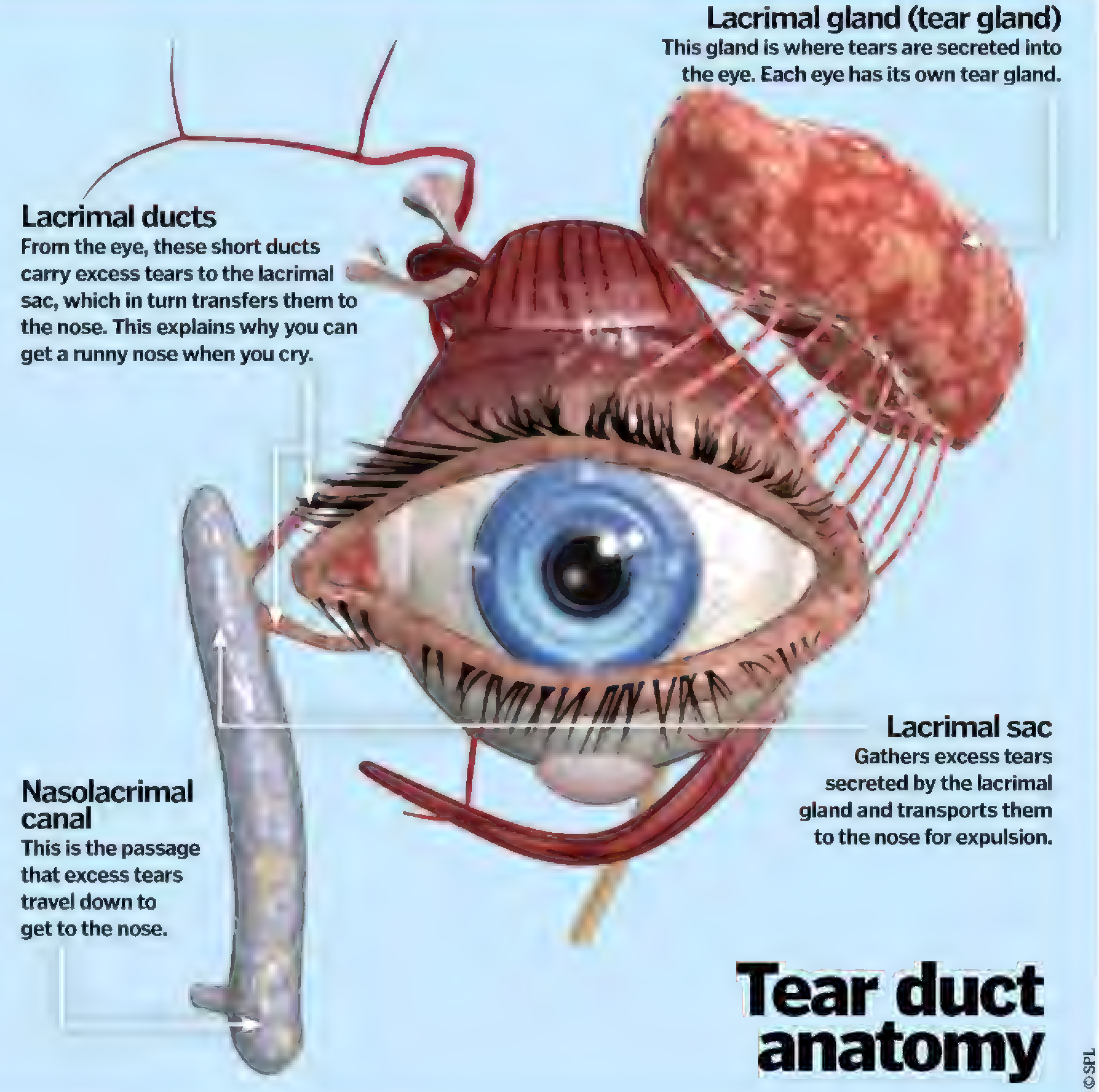
Receptors
These protruding proteins enable the virus to attach to the surface of the host cell.

How do tear ducts work?

Discover why we cry and what our tears made of

There are three types of tears and depending on the circumstance, different types of tears are produced. Basal tears keep the cornea lubricated, keep dust out of the eye and fight any infections within the eye. Basal tear fluid contains numerous chemicals, including potassium, sodium and glucose. Around one gram of fluid is secreted by the tear ducts in 24 hours, although this amount reduces with age. If crying occurs because of external stimuli, such as onion vapours or foreign objects entering the eye, reflex tears are released to clear the eye of irritants. The final type is what we would traditionally consider as 'crying'. This is the emotion-stimulated release of tears, normally due to extreme sadness, stress or pain. Unlike basal or reflex tears, the emotional variety contain more chemicals that work as natural painkillers, such as leucine enkephalin to combat physical and mental stresses.





"Both animals and humans bare their teeth when faced with an aggressive situation"

The trouble with teeth

Tooth decay, also often known as dental caries, affects the enamel and dentine of a tooth, breaking down tissue and creating fissures in the enamel. Two types of bacteria – namely Streptococcus mutans and Lactobacillus – are responsible for tooth decay.

Tooth decay occurs after repeated contact with acid-producing bacteria. Environmental factors also have a strong effect on dental health. Sucrose, fructose and glucose create large problems within the mouth, and diet can be an important factor in maintaining good oral health.

The mouth contains an enormous variety of bacteria, which collects around the teeth and gums. This is visible in the form of a sticky white substance called plaque. Plaque is known as a biofilm. After eating, the bacteria in the mouth metabolises sugar, which subsequently attacks the areas around the teeth.

Medication can also affect oral health, reducing the production of saliva, which offers natural protection and works against acidic matter. Various treatments can be applied to teeth that are damaged or decayed, these include extraction, filling or the replacement of teeth in the form of either dentures and implants.

The biological structures that are so versatile they enable us to eat a varied diet

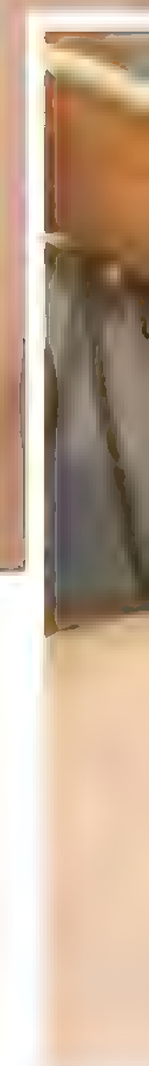
All about teeth

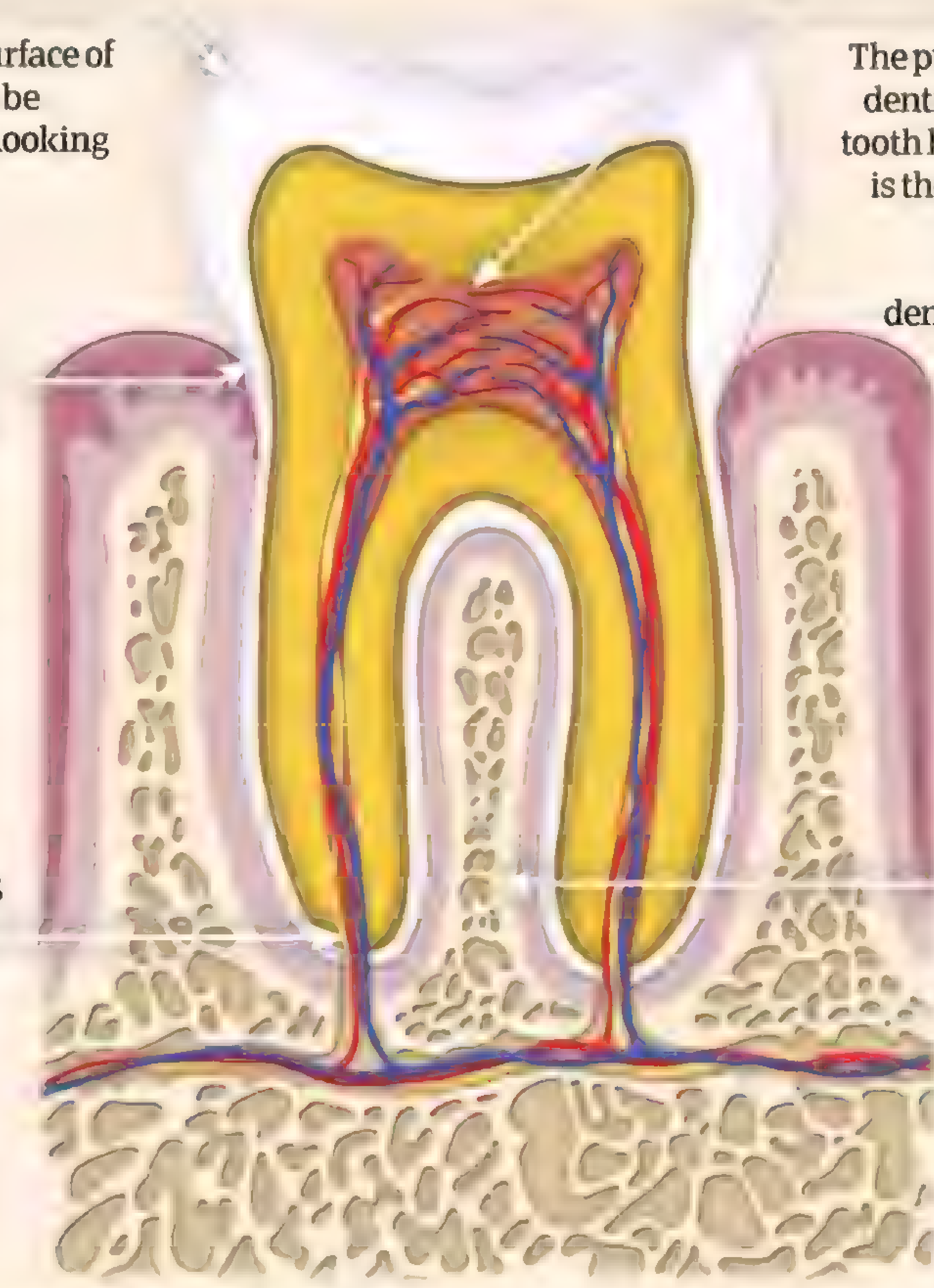
The primary function of teeth is to crunch and chew food. For this reason, teeth are made of strong substances – namely calcium, phosphorus and various mineral salts. The main structure of the tooth is dentine, this itself is enclosed in a shiny substance called enamel. This strong white coating is the hardest material found in the human body.

Humans have different types of teeth that function in various ways. Incisors tear at food, such as the residue found on bones, while bicuspids have long sharp structures that are also used for ripping. Bicuspids tear and crush while molars, which have a flatter surface, grind the food before swallowing. This aids digestion. Because humans have a varied array of teeth (called collective dentition) we are able to eat a complex diet of both meat and vegetables. Other species, such as grazing animals, have specific types of teeth. Cows, for example, have large flat teeth, which restricts them to a simple diet.

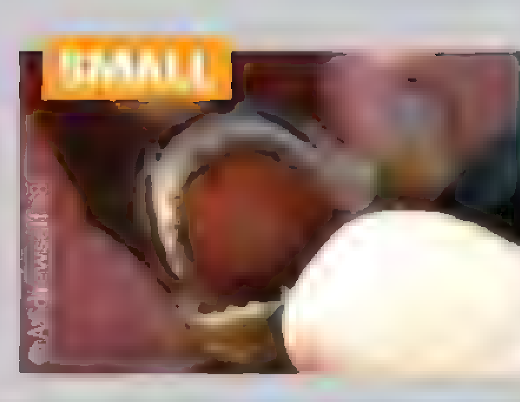
Teeth have many functions, in some cases they aid hunting but they also have strong psychological connotations. Both animals and humans bare their teeth when faced with an aggressive situation. Teeth are the most enduring features of the human body. Mammals are described as 'diphyodont', which means they develop two sets of teeth. In humans the teeth first appear at six months old and are replaced by secondary teeth after six or seven years. Some animals develop only one set of teeth, while sharks, for instance, grow a new set of teeth every two weeks.

With humans, tooth loss can occur through accident, gum disease or old age. From ancient times healers have sought to treat and replace the teeth with false ones. Examples of this practice can be seen from ancient Egyptian times and today, we see revolutionary new techniques in the form of dental implants, which are secured deep within the bone of the jaw.

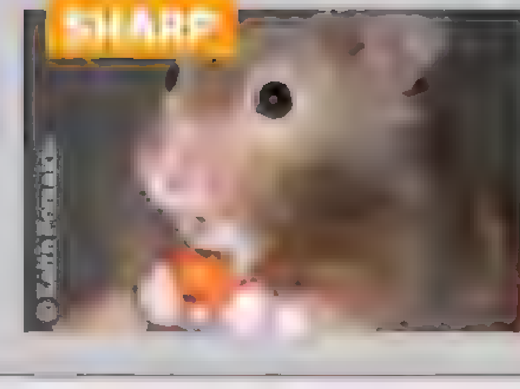




1. Hippopotamus
A hippopotamus has an enormous mouth that can measure up to 1.2 metres wide. They are equipped with a pair of huge and very dangerous incisors.



2. Piranha
Piranha teeth are very small but can be extremely sharp and are often used by the local populations of South America to create a variety of tools and weapons.



3. Hamster
A member of the rodent family, the hamster has teeth that grow continuously. They therefore need to grind their teeth on a hard substance to prevent overgrowth.

DID YOU KNOW? *The ancient Egyptians had severe problems with their teeth. They invented the world's first dental bridge*

Inside your mouth

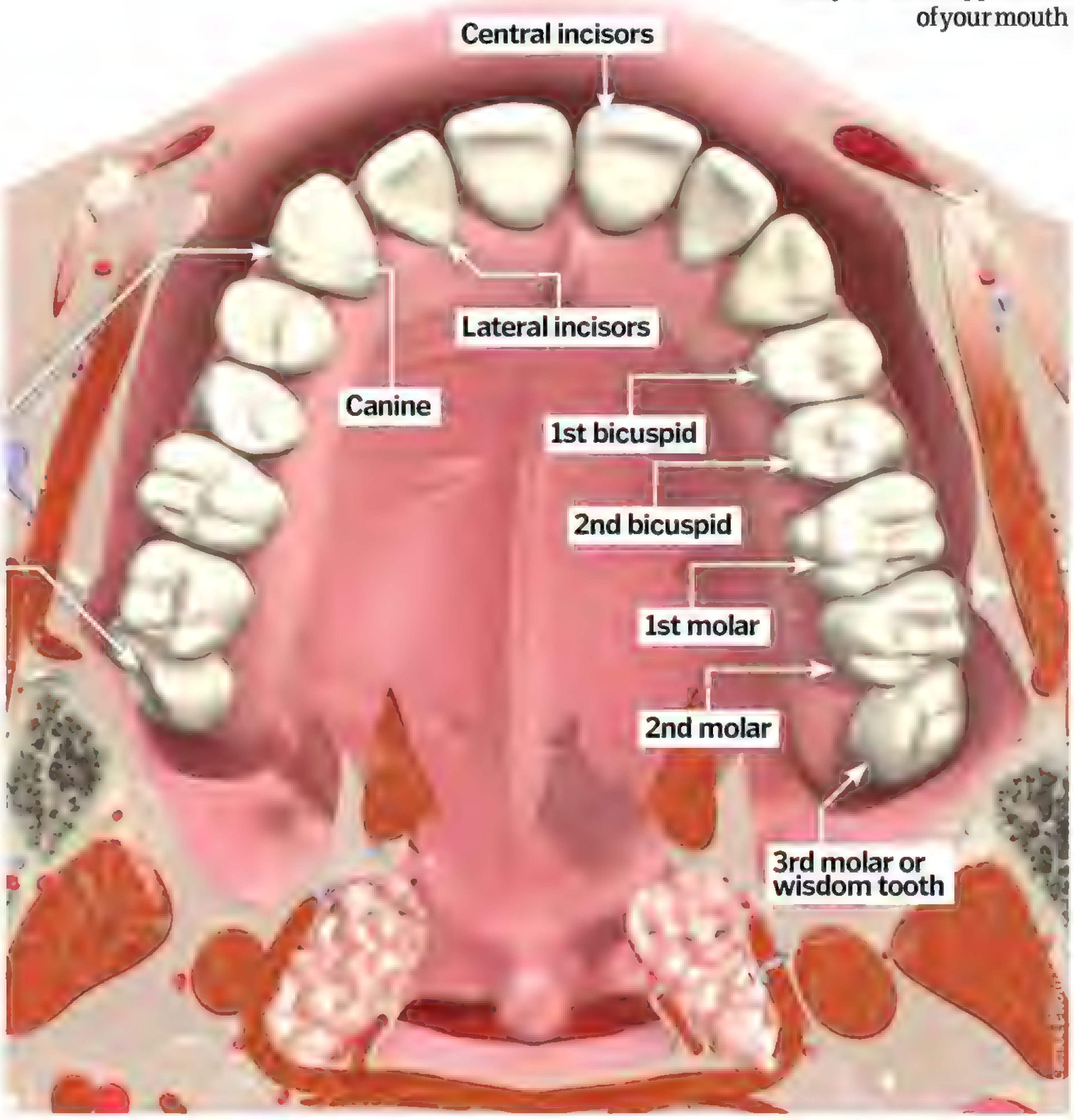
The upper and lower areas of the mouth are known as the maxilla and the mandible. The upper area of the mouth is attached to the skull bone and is often called the upper arch of the mouth, while the mandible is the v-shaped bone that carries the lower set of teeth.

Canine teeth
Long, pointed teeth that are used for holding and tearing at the food within the mouth.

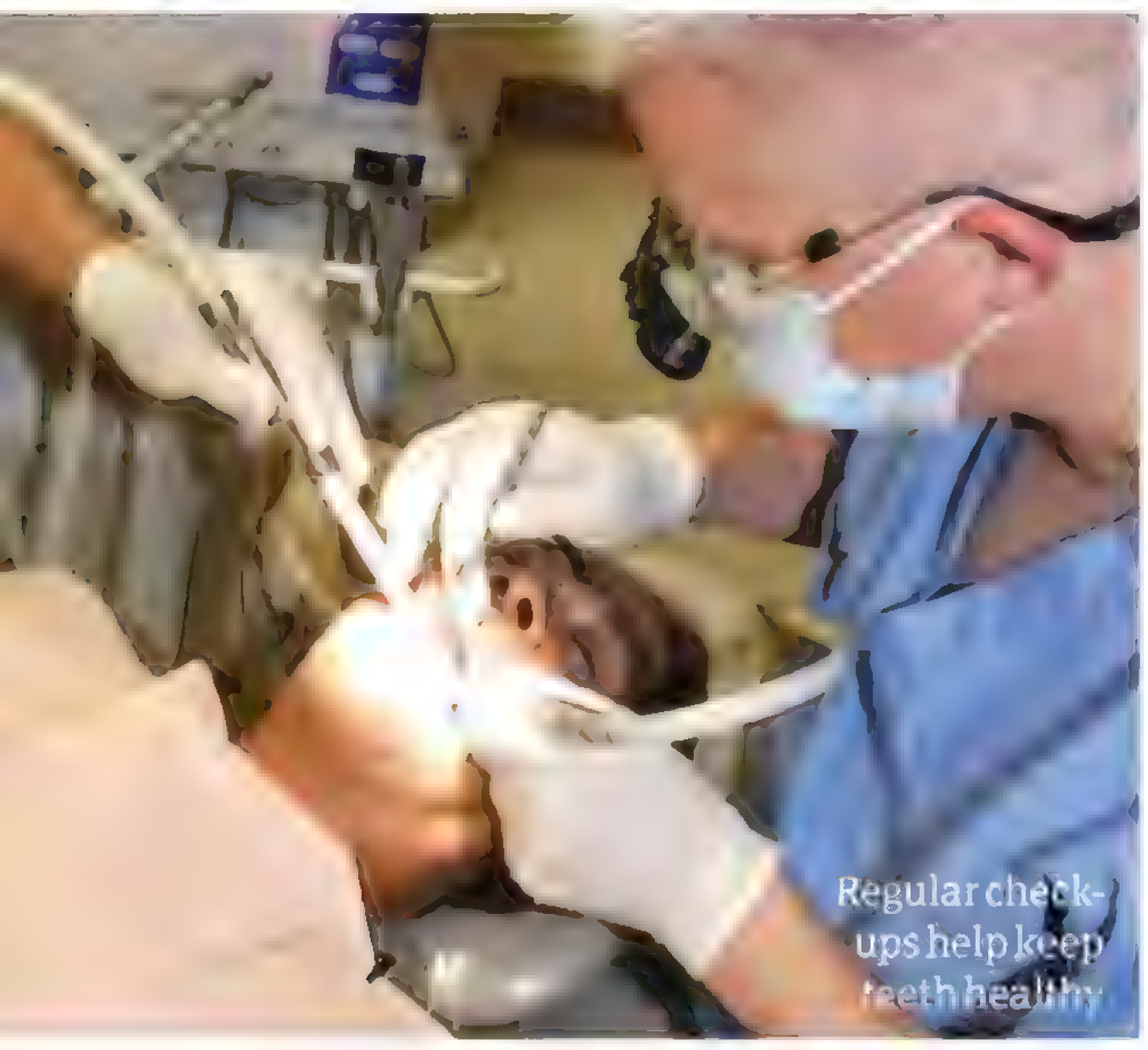
Wisdom teeth
Usually appear between the ages of 17 and 25, and often erupt in a group of four.

Maxilla

A layout of the upper area of your mouth



Adult teeth start coming through early on



Regular check-ups help keep teeth healthy

Eruption of teeth

The approximate ages at which the permanent teeth begin to erupt

Age 6
First molar

Age 7
Central incisor

Age 9
First premolar

Age 10
Second premolar

Age 11
Canine

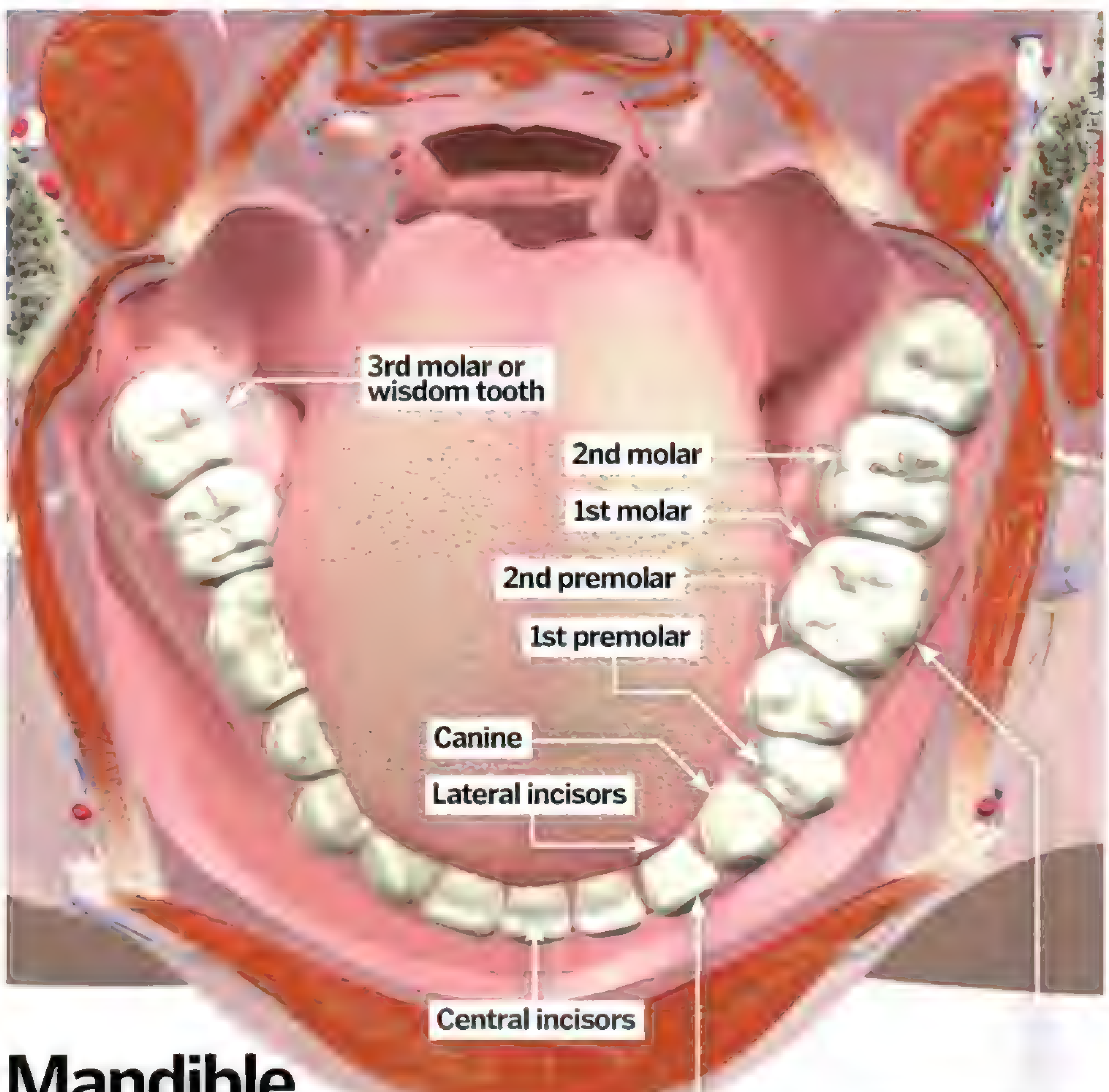
Age 12
Second molar

Age 17 to 21 or not at all
Third molar (wisdom teeth)

Tooth anatomy

The tooth is a complex structure. The enamel at the surface of the tooth is highly visible while the dentine is a hard but porous tissue found under the enamel. The gums provide a secure hold for the tooth, while the root is anchored right into the jawbone. In the centre of the tooth there is a substance called 'pulp' which contains nerves and blood vessels, the pulp nourishes the dentine and keeps the tooth healthy.

Tooth formation begins before birth. Normally there are 20 primary teeth (human baby teeth) and later, 28 to 32 permanent teeth, which includes the wisdom teeth. Of the primary teeth, ten are found in the maxilla (the upper jaw) and ten in the mandible (lower jaw), while the mature adult has 16 permanent teeth in the maxilla and 16 in the mandible.



Mandible

A look inside your lower jawbone

Lateral and central incisors
Incisor comes from the Latin word 'to cut', they are used to grip and bite.

First and second premolar teeth
The premolar or bicuspids are located between the canine and molar teeth. They are used for chewing.

Learn more
For further reading, why not check out *Teeth Are Not For Biting* (2003), Elizabeth Verdick, Free Spirit Publishing; or *DIY Dentistry: And Other Alarming Inventions* (2008), Andy Riley, New English Library.

> "If the early embryo splits into two clumps before this, it may develop into identical twins"

HOW DOES AN EMBRYO DEVELOP?

Discover how a fertilised egg transforms into an embryo and eventually a new human being

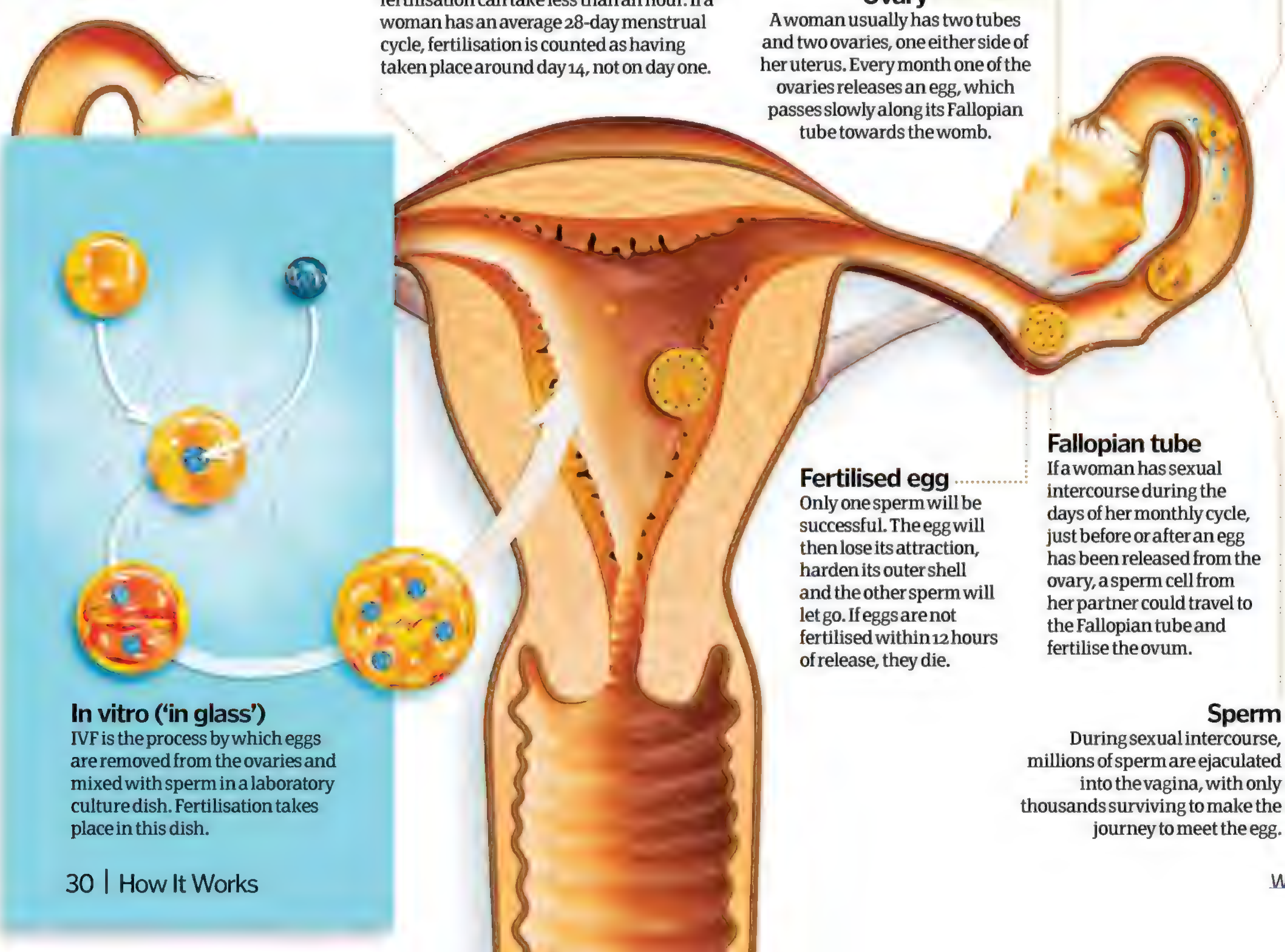
After fertilisation, the single-celled zygote splits into two, then the two cells double to four, four to eight and so on. The journey along the Fallopian tube is quite slow, while growth continues. On its way, the zygote divides to make a clump of 32 cells, known as the morula stage. If the early embryo splits into two clumps before this, it may develop into identical twins. Every cell in the morula could still become part of the growing embryo.

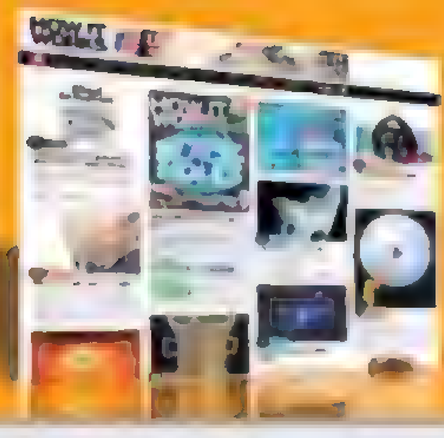
By the time the womb cavity is reached, the cell cluster becomes hollow and filled with fluid; it is now referred to as the blastocyst. A blastocyst is an embryo that has developed to the stage where it has two different cell types: the surface cells, or outer coat, will become, among other things, the placenta that nourishes the baby; the inner cells, known as the inner cell mass, will become the foetus itself. On contact, the blastocyst burrows into the uterine wall for nourishment; this process is known as implantation. Blastocyst formation usually occurs on the fifth day after fertilisation.

The embryonic stage begins in the fifth week. From weeks five to eight, development is rapid. Major body organs and systems, including the brain, lungs, liver and stomach, will begin to emerge. At this time, the first bone cells will also appear. By the end of the eighth week, the embryo is known as a foetus and increasingly looks like a mini human.

Fertilisation and IVF explained

Natural fertilisation takes place via sexual intercourse. An egg, or ovum, is released by an ovary and is fertilised by a sperm. Fertilisation occurs when the sperm and egg unite in one of the female's Fallopian tubes. The fertilised egg, known as a single-celled zygote, then travels to the uterus, where it implants into the uterine lining. In vitro fertilisation (IVF) is a form of assisted reproductive technology, where the sperm nucleus is combined with an egg cell in a lab. The resultant embryo is manually introduced to the uterus, where it develops in the same way as a natural conception.





AMAZING VIDEO!

SCAN THE QR CODE FOR A QUICK LINK

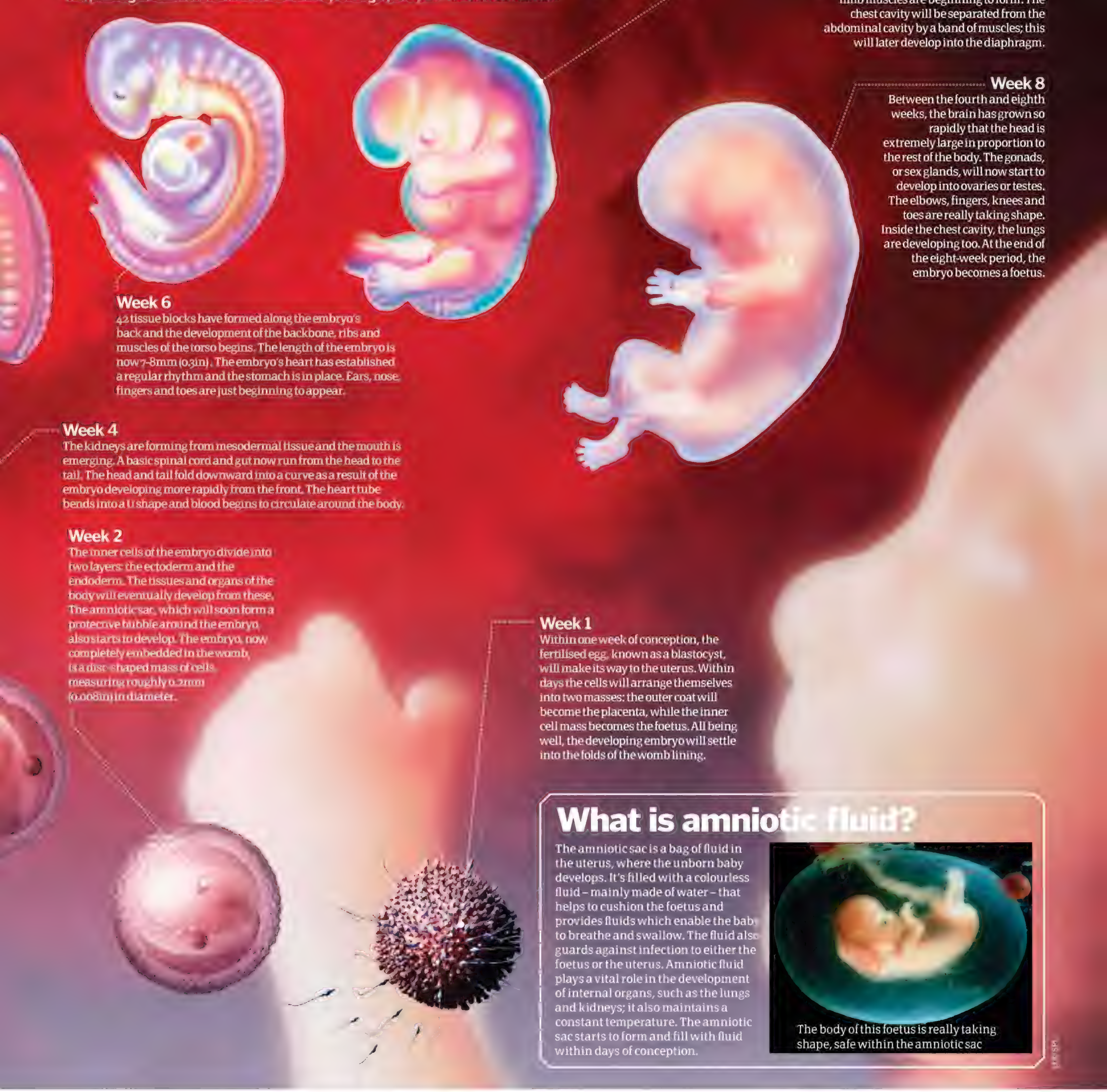
Watch the developmental cycle of an embryo

www.howitworksdaily.com

DID YOU KNOW? *In 2009, almost two per cent of all babies born in the UK were conceived as a result of IVF*

Journey of an embryo

The first eight weeks is an immense time of change for a just-conceived human



Week 7

The embryo's eyelids begin to form from a single membrane that remains fused for several days. At this stage in development, the limb muscles are beginning to form. The chest cavity will be separated from the abdominal cavity by a band of muscles; this will later develop into the diaphragm.

Week 8

Between the fourth and eighth weeks, the brain has grown so rapidly that the head is extremely large in proportion to the rest of the body. The gonads, or sex glands, will now start to develop into ovaries or testes. The elbows, fingers, knees and toes are really taking shape. Inside the chest cavity, the lungs are developing too. At the end of the eight-week period, the embryo becomes a foetus.

Week 6

42 tissue blocks have formed along the embryo's back and the development of the backbone, ribs and muscles of the torso begins. The length of the embryo is now 7-8mm (0.3in). The embryo's heart has established a regular rhythm and the stomach is in place. Ears, nose, fingers and toes are just beginning to appear.

Week 4

The kidneys are forming from mesodermal tissue and the mouth is emerging. A basic spinal cord and gut now run from the head to the tail. The head and tail fold downward into a curve as a result of the embryo developing more rapidly from the front. The heart tube bends into a U shape and blood begins to circulate around the body.

Week 2

The inner cells of the embryo divide into two layers: the ectoderm and the endoderm. The tissues and organs of the body will eventually develop from these. The amniotic sac, which will soon form a protective bubble around the embryo, also starts to develop. The embryo, now completely embedded in the womb, is a disc-shaped mass of cells measuring roughly 0.2mm (0.008in) in diameter.

Week 1

Within one week of conception, the fertilised egg, known as a blastocyst, will make its way to the uterus. Within days the cells will arrange themselves into two masses: the outer coat will become the placenta, while the inner cell mass becomes the foetus. All being well, the developing embryo will settle into the folds of the womb lining.

What is amniotic fluid?

The amniotic sac is a bag of fluid in the uterus, where the unborn baby develops. It's filled with a colourless fluid – mainly made of water – that helps to cushion the foetus and provides fluids which enable the baby to breathe and swallow. The fluid also guards against infection to either the foetus or the uterus. Amniotic fluid plays a vital role in the development of internal organs, such as the lungs and kidneys; it also maintains a constant temperature. The amniotic sac starts to form and fill with fluid within days of conception.

The body of this foetus is really taking shape, safe within the amniotic sac

Exploring the sensory system

The complex senses of the human body and how they interact is vital to the way we live day to day

The sensory system is what enables us to experience the world. It can also warn us of danger, trigger memories and protect us from damaging stimuli, such as scorching hot surfaces. The human sensory system is highly developed, with its many components detecting both physical and emotional properties of the environment. For example, it can interpret chemical molecules in the air into smells, moving molecules of sound into noises and pressure placed on the skin into touch. Indeed, some of our senses are so finely tuned they allow reactions within milliseconds of detecting a new sensation.

The five classic senses are sight, hearing, smell, taste and touch. We need senses not only to interpret the world around us, but also to function within it. Our senses enable us to modify our movements and thoughts, and sometimes they directly feed signals into muscles. The sensory nervous system that lies behind this is made up of receptors, nerves and dedicated parts of the brain.

There are thousands of different stimuli that can trigger our senses, including light, heat, chemicals in food and pressure. These 'stimulus modalities' are then detected by specialised receptors, which convert them into sensations such as hot and cold, tastes, images and touch. The incredible receptors – like the eyes, ears, nose, tongue and skin – have adapted over time to work seamlessly together and without having to be actively 'switched on'.

However, sometimes the sensory system can go wrong. There are hundreds of diseases of the senses, which can have both minor effects, or a life-changing impact. For example, a blocked ear can affect your balance, or a cold your ability to smell – but these things don't last for long.

In contrast, say, after a car accident severing the spinal cord, the damage can be permanent. There are some very specific problems that the sensory system can bring as well. After an amputation, the brain can still detect signals from the nerves that used to connect to the lost limb. These sensations can cause excruciating pain; this particular condition is known as phantom limb syndrome.

However the sensory system is able to adapt to change, with the loss of one often leading to others being heightened. Our senses normally function to gently inhibit each other in order to moderate individual sensations. The loss of sight from blindness is thought to lead to strengthening of signals from the ears, nose and tongue. Having said this, it's certainly not universal among the blind, being more common in people who have been blind since a young age or from birth. Similarly, some people who listen to music like to close their eyes, as they claim the loss of visual input can enhance the audio experience.

Although the human sensory system is well developed, many animals out-perform us. For example, dogs can hear much higher-pitched sounds, while sharks have a far better sense of smell – in fact, they can sniff out a single drop of blood in a million drops of water!

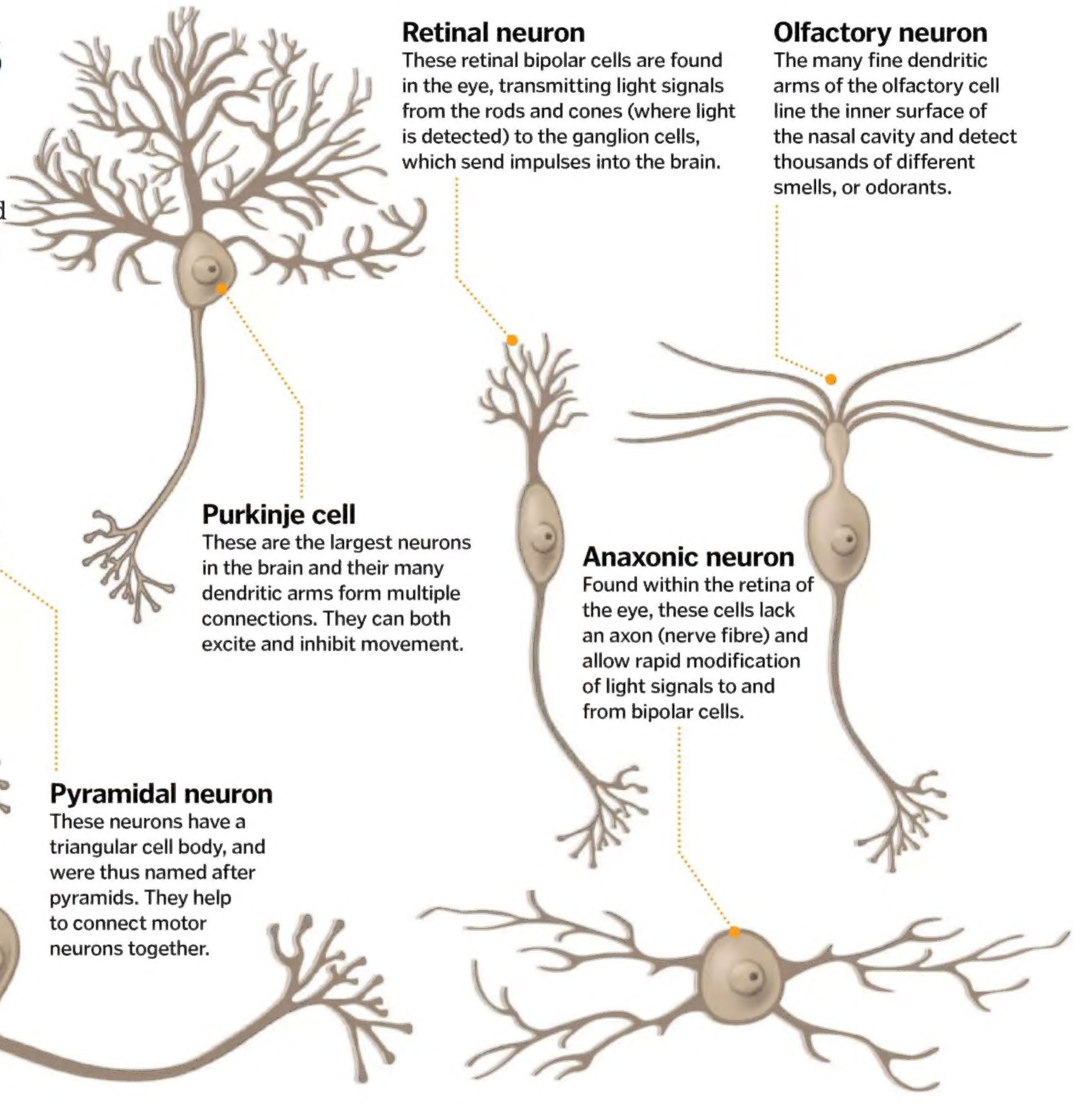
Which creatures can have up to a hundred eyes?

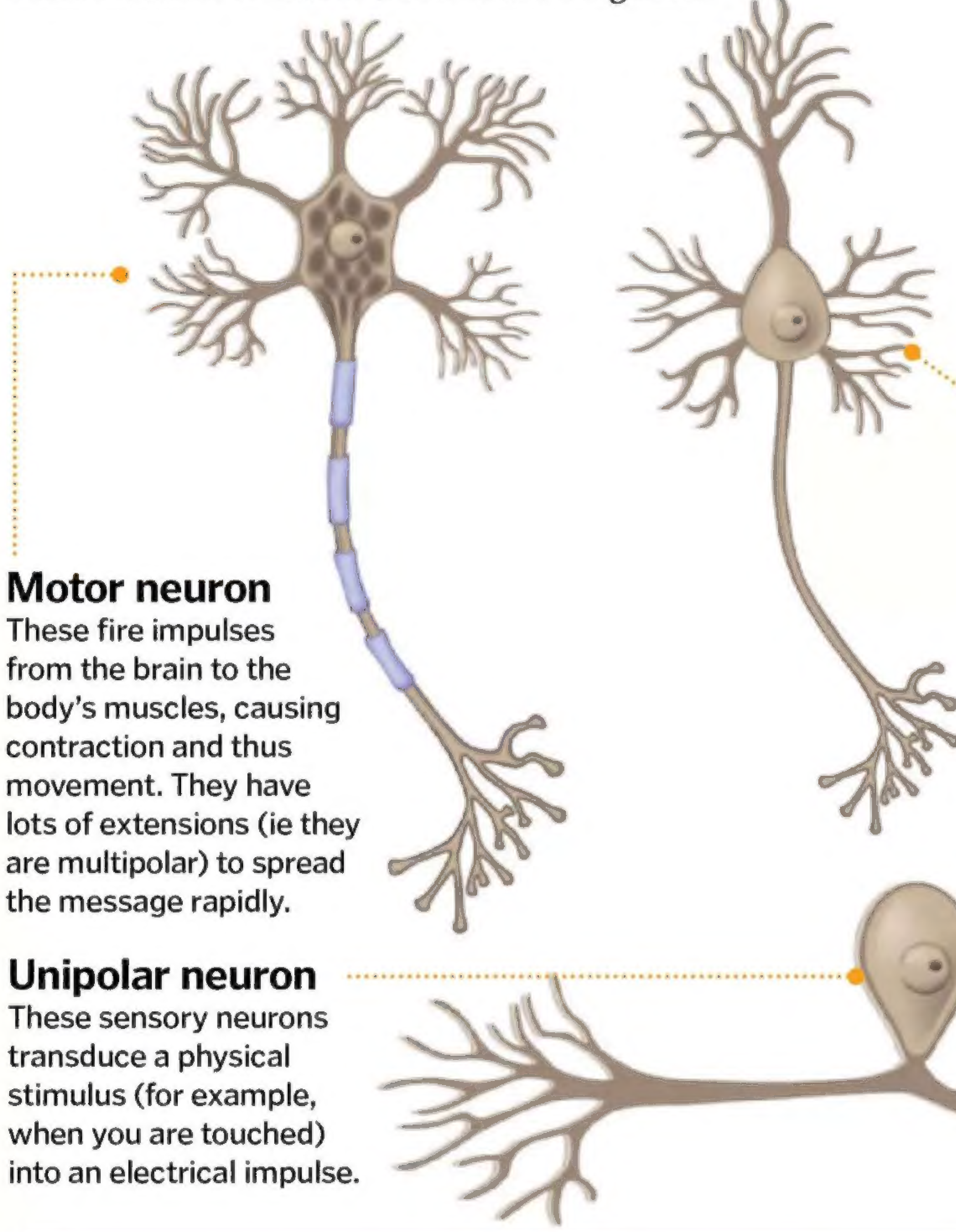
A Scallops **B** Spiders **C** Peacocks

Answer:
Scallops are an underwater mollusc that amazingly can have as many as 100 eyes! Although they can't create as clear a picture as our eyes, they can detect enough light and movement to warn them of oncoming predators.

Body's messengers

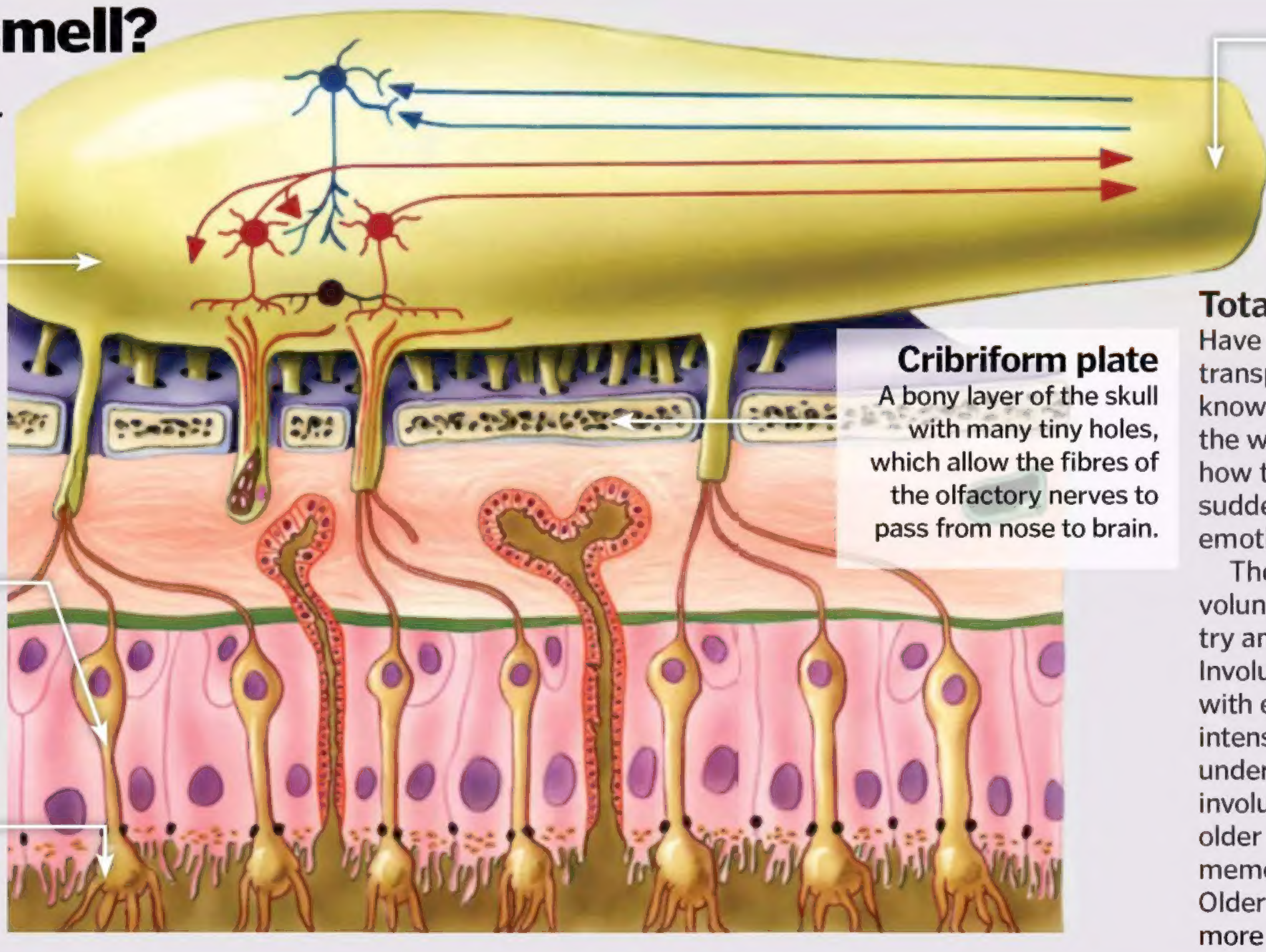
The sensory system is formed from neurons. These are specialised nerve cells which transmit signals from one end to the other – for example, from your skin to your brain. They are excitable, meaning that when stimulated to a certain electrical/chemical threshold they will fire a signal. There are many different types, and they can interconnect to affect each other's signals.





How do we smell?

Find out how our nose and brain work together to distinguish scents



Total recall

Have you ever smelt something that transported you back in time? This is known as the Madeleine effect because the writer Marcel Proust once described how the scent of a madeleine cake suddenly evoked strong memories and emotions from his childhood.

The opposite type of recall is voluntary memory, where you actively try and remember a certain event. Involuntary memories are intertwined with emotion and so are often the more intense of the two. Younger children under the age of ten have stronger involuntary memory capabilities than older people, which is why these memories thrust you back to childhood. Older children use voluntary memory more often, eg when revising for exams.

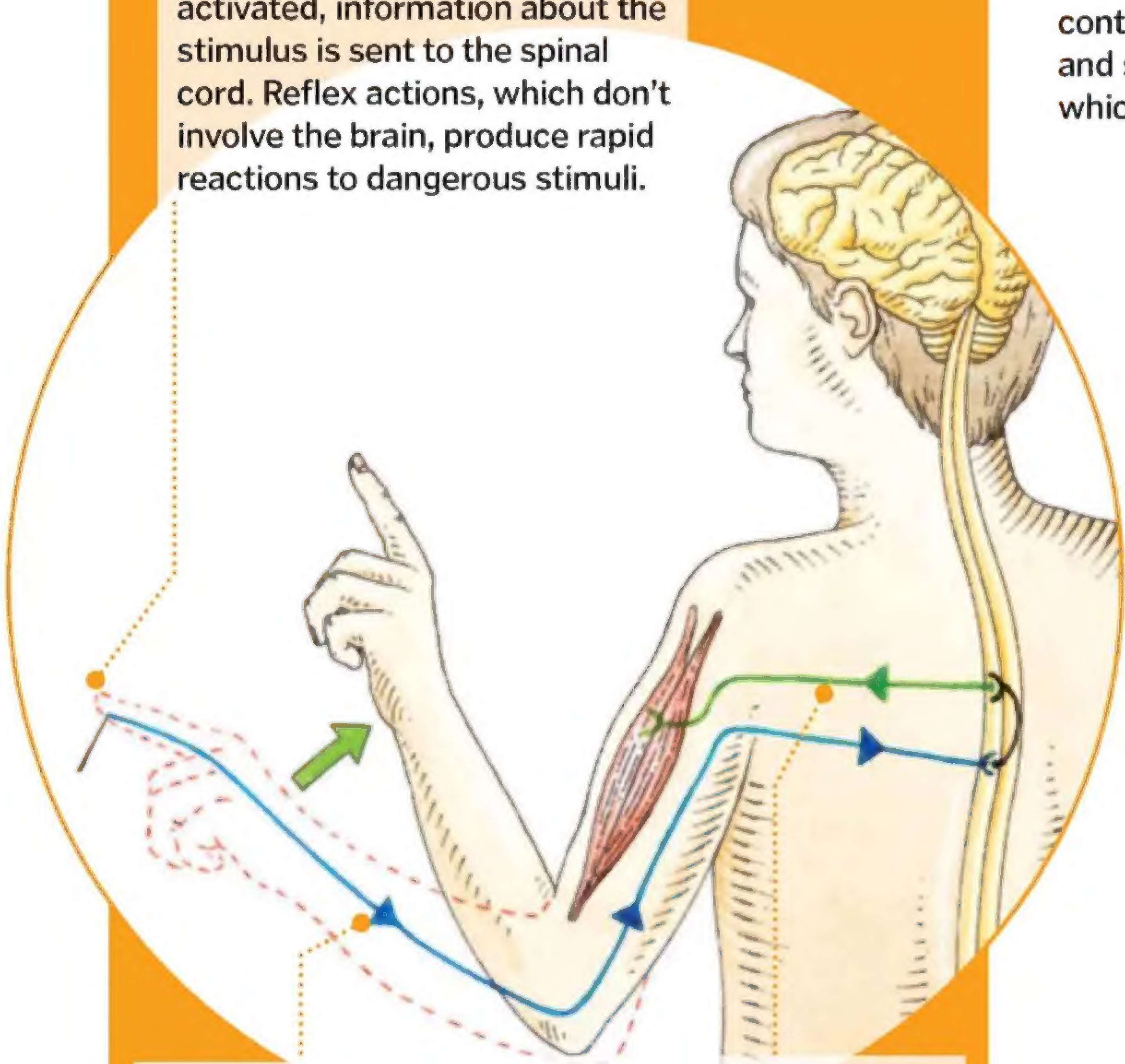
> *"Sights take on smells, a conversation can take on tastes, and music can feel textured"*

Understanding lightning reflexes

Have you ever felt something scorching hot or freezing cold, and pulled your hand away without even thinking about it? This reaction is a reflex. Your reflexes are the most vital and fastest of all your senses. They are carried out by the many 'reflex arcs' located throughout the body.

For example, a temperature-detecting nerve in your finger connects to a motor nerve in your spine, which travels straight to your biceps, creating a circular arc of nerves. By only having two nerves in the circuit, the speed of the reflex is as fast as possible. A third nerve transmits the sensation to the brain, so you know what's happened, but this nerve doesn't interfere with the arc; it's for your information only. There are other reflex arcs located within your joints, so that, say, if your knee gives way or you suddenly lose balance, you can compensate quickly.

1. Touch receptor
When a touch receptor is activated, information about the stimulus is sent to the spinal cord. Reflex actions, which don't involve the brain, produce rapid reactions to dangerous stimuli.

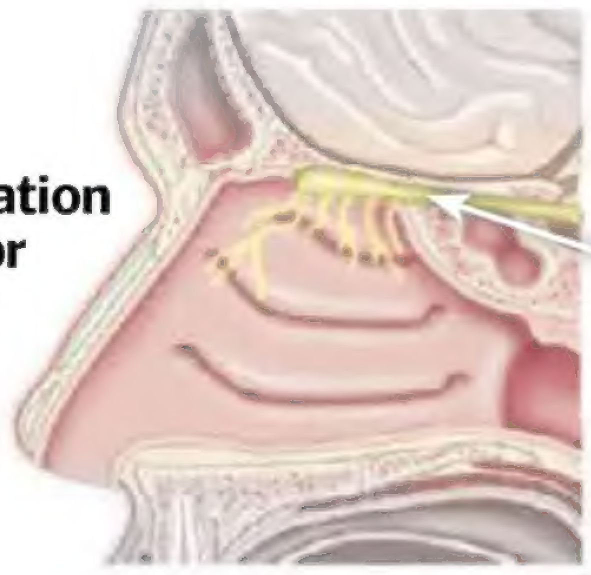


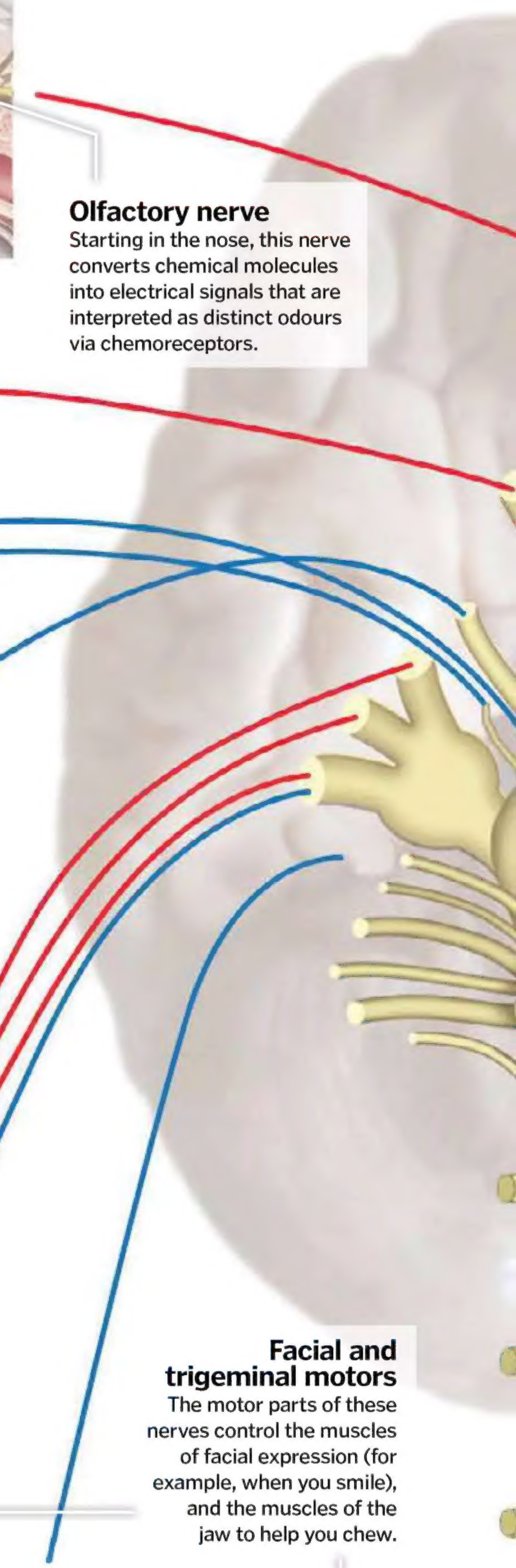
2. Signal sent to spine
When sensory nerve endings fire, information passes through nerve fibres to the spinal cord.

3. Motor neurons feed back
The signals trigger motor neurons that initiate their own impulses that feed back to the muscle, telling it to move the body part.

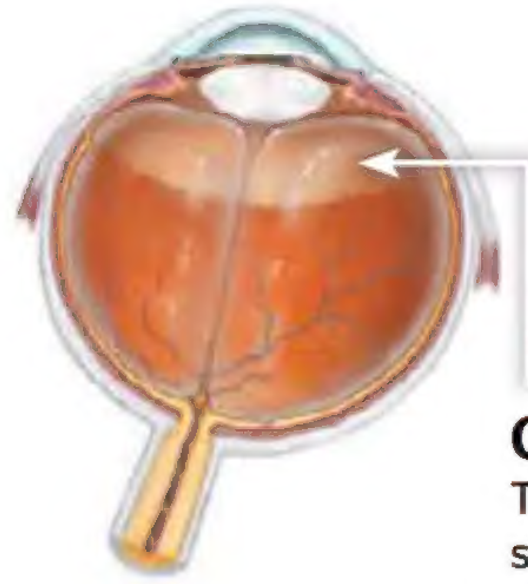
Key nerves

These transmit vital sensory information to our brain while also sending motor function signals all around the body

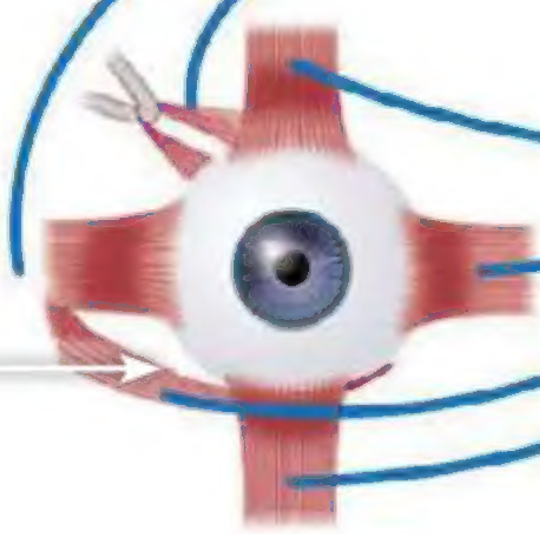




Olfactory nerve
Starting in the nose, this nerve converts chemical molecules into electrical signals that are interpreted as distinct odours via chemoreceptors.



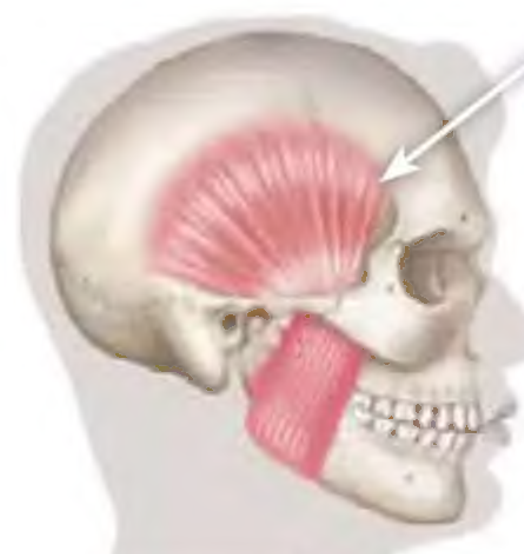
Optic nerve
The optic nerves convert light signals into electrical impulses, which are interpreted in the occipital lobe at the back of the brain. The resulting image is seen upside down and back to front, but the brain reorients the image.



Eye movements
The trochlear, abducent and oculomotor nerves control the eye muscles and so the direction in which we look.

Trigeminal nerve
This nerve is an example of a mechanoreceptor, as it fires when your face is touched. It is split into three parts, covering the top, middle and bottom thirds of your face.

Facial and trigeminal motors
The motor parts of these nerves control the muscles of facial expression (for example, when you smile), and the muscles of the jaw to help you chew.



5 TOP FACTS HUMAN SENSES

A matter of taste
1 There are about 9,000 taste buds on the tongue and throat. These convert chemicals found in saliva into electrical signals, split into five tastes: sweet, salt, sour, bitter and umami.

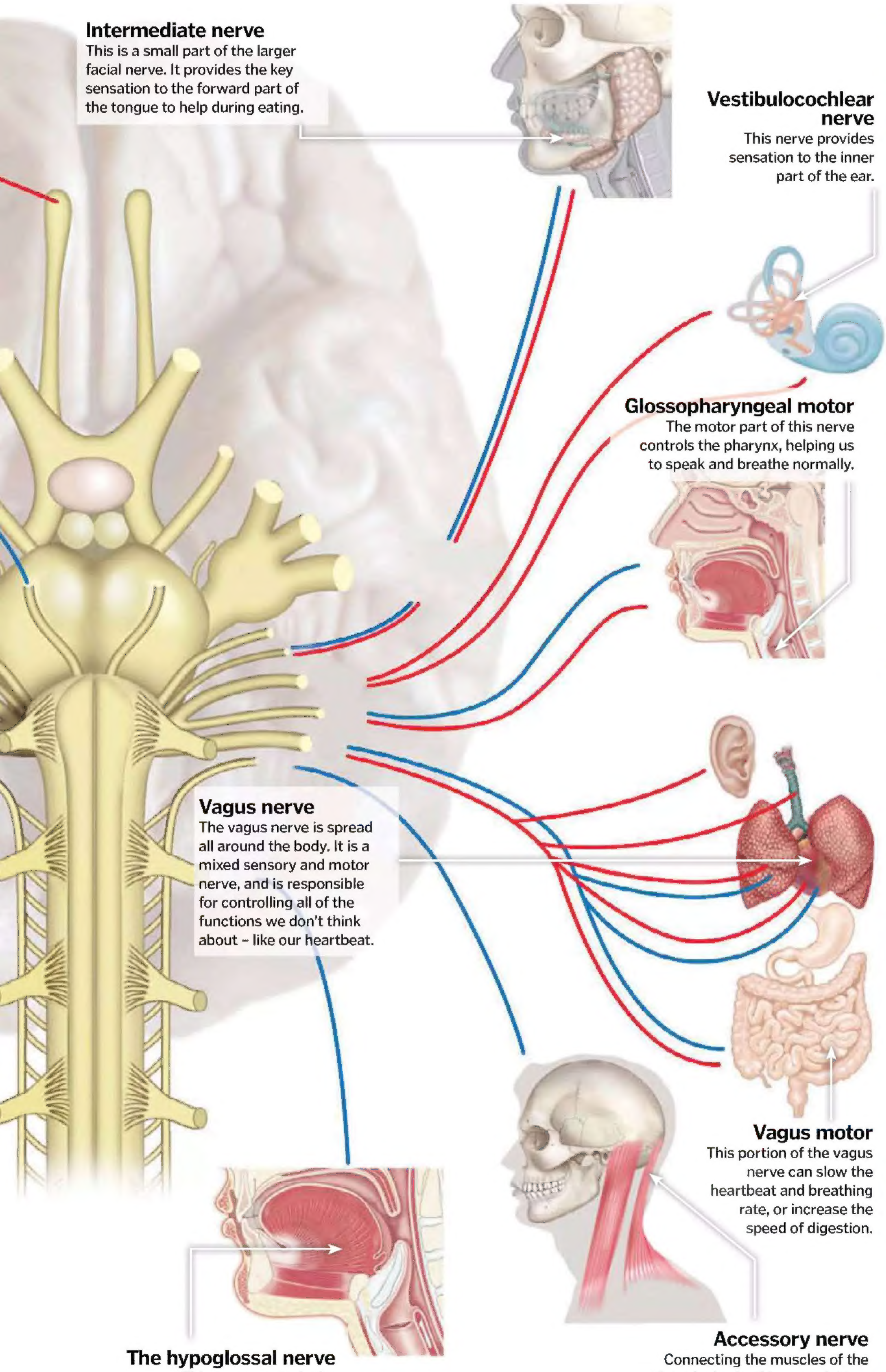
Smell vs sight
2 Odours offer better memory recall than visual cues, as smell is tied to emotion. Looking at an old photograph can trigger memory, but a smell can evoke how you felt at the time.

Sensitive skin
3 Human skin contains over half a million sensory receptors. These are of the highest concentration in the fingertips, the ends of the toes and lips, where they're most needed.

Upside down
4 The images formed in the occipital cortex are upside down, before the brain flips them. However babies start by seeing upside down, until the brain learns to adapt.

Staying steady
5 Ears do more than detect sound. The fluid and fine hairs in the inner ear maintain balance. If you spin round and stop, this fluid is still moving which is why we get dizzy.

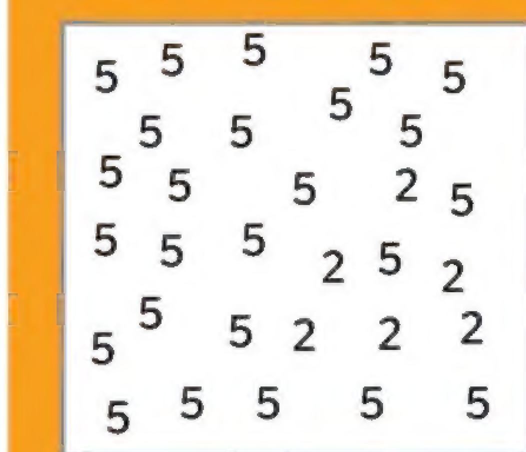
DID YOU KNOW? The three smallest bones in the human body – the hammer, anvil and stirrup – are located in the middle ear



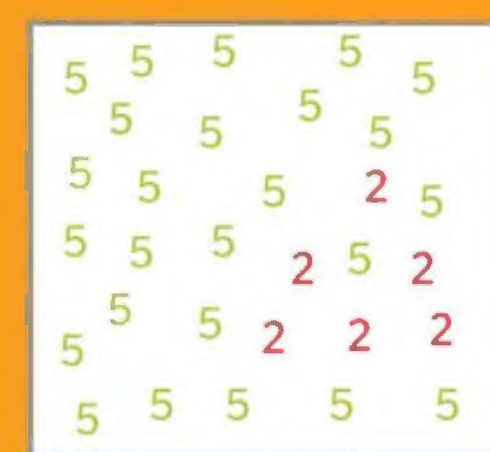
Crossed senses

Synaesthesia is a fascinating, if yet completely understood, condition. In some people, two or more of the five senses become completely linked so when a single sensation is triggered, all the linked sensations are activated too. For example, the letter 'A' might always appear red, or seeing the number '1' might trigger the taste of apples. Sights take on smells, a conversation can take on tastes and music can feel textured.

People with synaesthesia certainly don't consider it to be a disorder or a disease. In fact, many do not think what they sense is unusual, and they couldn't imagine living without it. It often runs in families and may be more common than we think. More information about the condition is available from the UK Synaesthesia Association (www.uksynaesthesia.com).



Non-synaesthetes struggle to identify a triangle of 2s among a field of number 5s.



But a synaesthete who sees 2s as red and 5s as green can quickly pick out the triangle.

A patient's sense of proprioception is being put to the test here

Is there really a 'sixth sense'?

Our sense of balance and the position of our bodies in space are sensations we rarely think about and so are sometimes thought of as a 'sixth sense'. There is a whole science behind them though, and they are collectively called proprioception. There are nerves located throughout the musculoskeletal system (for example, within your muscles, tendons, ligaments and joints) whose job it is to send information on balance and posture back to the brain. The brain then interprets this information rapidly and sends instructions back to the muscles to allow for fine adjustments in balance. Since you don't have to think about it and you can't switch it off, you don't know how vital these systems are until they're damaged. Sadly some medical conditions, including strokes, can affect our sense of proprioception, making it difficult to stand, walk, talk and move our limbs.

HOW IT WORKS

IF YOU LIKED THIS, WHY NOT CHECK OUT AMAZING CHEMISTRY AND AMAZING PHYSICS